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American Wood-Preservers' Association

1921

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C. MARSHALL TAYLOR
PRESIDENT, 1921

PROCEEDINGS

OF THE

Seventeenth Annual Meeting

OF THE

American Wood-Preservers' Association

HOTEL SAINT FRANCIS,
SAN FRANCISCO, CAL.
JANUARY 25, 26, 27, 1921.

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AMERICAN WOOD-PRESERVERS' ASSOCIATION

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AMERICAN WOOD-PRESERVERS' ASSOCIATION

CONSTITUTION

(Amended 1912, 1915, 1916, 1920)

ARTICLE I

Name and Objects

SECTION 1. The name of this Association shall be the AMERICAN WOOD-PRESERVERS' ASSOCIATION.

SECTION 2. The objects of the Association shall be the promotion of knowledge of the materials, methods, and principles involved in the economic design, location, construction, maintenance, and operation of wood-preserving works; the standardization of specifications for wood preservatives and for their introduction into the material to be preserved; and the maintenance of high standards of business ethics in the wood-preserving industry.

SECTION 3. The means to be used for these purposes shall be meetings for the presentation and discussion of reports of the experiences and investigations of its members and others, for the interchange of ideas, and for social intercourse; the publication of desirable information; and co-operation with organizations or individuals in work affecting wood-preserving.

ARTICLE II

Membership

SECTION 1. The Association shall consist of Corporate, Associate, Probate, and Honorary members.

SECTION 2. A Corporate Member shall be an executive, an administrator, or an operative in a wood-preserving organization; an officer of a public-utility corporation using treated wood whose duties cover the purchasing, inspecting, treating, or distribution of such material; a chemist or an engineer in the employ of a city, county, state, nation, or public-utility corporation; a consulting chemical, civil, electrical, forest, or mechanical engineer; or a professor or an instructor in an institution of learning.

SECTION 3. An Associate Member shall be any person or association of persons interested in wood preservation or in the sale of material or equipment used in the wood-preserving industry.

SECTION 4. A Probate Member shall be an employe of a wood-preserving or inspecting organization who is not eligible for Corporate Membership.

SECTION 5. An Honorary Member shall be a person of acknowledged eminence in the wood-preserving industry or the sciences relating thereto.

SECTION 6. Corporate Members shall have all the rights and privileges of the Association.

SECTION 7. Associate Members shall have all the rights of Corporate Members, except those of voting or holding office.

SECTION 8. Probate Members shall have all the rights of Corporate Members, except those of voting or holding office, for five years from the date of their admission, when their status shall be determined by the Executive Committee.

SECTION 9. Honorary Members shall have all the rights of Corporate Members, except that of holding office, and shall be exempt from the payment of dues.

ARTICLE III

Admissions and Expulsions

SECTION 1. Applications for membership and resignations from membership shall be transmitted to the Secretary-Treasurer, the former on a form prescribed by the Executive Committee and endorsed by a Corporate or an Honorary Member. The Secretary-Treasurer shall forward a copy of each application for membership to each member of the Executive Committee, the affirmative votes of a majority of whom shall admit the candidate.

SECTION 2. Proposals for Honorary Membership shall be made by at least ten members, none of whom shall be a member of the Executive Committee. The nominee shall be declared an Honorary Member if he receives the unanimous vote of the Executive Committee or the votes of two-thirds of the Corporate and Honorary members present and voting at an Annual Meeting; provided, however, that there shall be no election to Honorary Membership when such election would make the total number of Honorary Members greater than three per cent of the total number of Corporate Members.

SECTION 3. Any member of the Association who resigns while in good standing may be reinstated without paying a second admission fee, provided his application is approved by two-thirds of the Executive Committee.

SECTION 4. For unbecoming conduct a member may be expelled by the votes of two-thirds of the Corporate and Honorary Members present and voting at an Annual Meeting, after the member has been served with written particulars as to his offense by the Executive Committee, and had an opportunity to be heard by it or by the members at an Annual Meeting.

SECTION 5. The Executive Committee shall accept the resignation, tendered in writing, of any member whose dues are paid.

ARTICLE IV

Dues

SECTION 1. On admission to the Association, members shall pay fees as follows: Corporate Members, $10.00; Associate Members, $15.00; Probate Members, $5.00, which shall include their first dues.

SECTION 2. The annual dues, payable during the first two months of the calendar year, shall be as follows: Corporate Members, $10.00; Associate Members, $10.00; Probate Members, $5.00.

SECTION 3. Members admitted after March 31 shall be exempt from the payment of dues until the following January 1, unless they desire to vote or to receive the current publications of the Association, in which case they shall pay one-half of the annual dues.

SECTION 4. Any member whose dues are unpaid on April 1 shall not receive the publications of the Association, and if his dues are not paid by December 31, his membership shall be canceled, except as provided for in Section 5 of this Article.

SECTION 5. The Executive Committee may extend the time for paying or remit the dues of any Corporate or Probate members who are unable to pay them.

ARTICLE V

Officers

SECTION 1. The officers of the Association shall be Corporate Members and shall consist of a President, a First Vice-President, a Second Vice-President, a Secretary-Treasurer, and six Members of Executive Committee, who, together with the last Past-President who is a Corporate Member, shall constitute the Executive Committee in which responsibility for the government of the Association shall be vested. The President shall be chosen from the nine eligible members of the Executive Committee.

SECTION 2. No two or more officers in any year shall be members of the same business organization.

SECTION 3. The President, the First Vice-President, the Second Vice-President, the Secretary-Treasurer, and two Members of Executive Committee shall be elected at each Annual Meeting.

SECTION 4. The terms of the President, Vice-Presidents, and Secretary-Treasurer shall begin at the close of the Annual Meeting at which they are elected and continue until their successors are elected and have qualified. The six Members of Executive Committee shall serve three years, two being elected each year.

SECTION 5. A vacancy in the office of President shall be filled by the Vice-Presidents in order.

SECTION 6. A vacancy in any office other than that of President shall be filled by an appointee of the Executive Committee.

SECTION 7. The President shall not be eligible for re-election to that office until three others have filled it. A Vice-President shall not be eligible for re-election to the same office until one other has filled it.

ARTICLE VI

Nomination and Election of Officers

SECTION 1. At each Annual Meeting six Corporate Members who are not officers shall be elected, together with the three last Past-Presidents who are Corporate Members, to serve one year as a Nominating Committee, of which the senior Past-President shall be chairman.

SECTION 2. The Nominating Committee shall nominate one eligible member for each office and for each membership in the Nominating Committee and shall send its list of nominees to the Secretary-Treasurer before October 15. Any vacancies that may occur in the list of nominees before it is sent to the members shall be filled by the Executive Committee.

SECTION 3. The voting shall not be restricted to the names presented by the Nominating Committee. Any member may file with the Secretary-Treasurer before November 1 the name of a candidate for any office.

SECTION 4. The ballot, with envelopes for secret voting, shall be sent to each member before December 1. It must contain the names of all nominees for each office, arranged alphabetically where there is more than one name for any office, with the nominees of the Nominating Committee plainly indicated.

SECTION 5. Members may scratch or substitute the name of any nominee for any office.

SECTION 6. Ballots shall be sealed and sent or delivered to the Secretary-Treasurer before the polls close, prior to which time a voter may withdraw or replace his ballot.

SECTION 7. The polls shall be closed at noon on the first day of the Annual Meeting, and the ballots shall be counted by one Corporate and four Associate or Probate Members, appointed tellers by the presiding officer at the Annual Meeting.

SECTION 8. The persons who receive the highest number of votes for the offices for which they are candidates shall be declared elected. In case of a tie between candidates for the same office, the members present at the Annual Meeting shall elect the officer from the candidates so tied. The presiding officer shall announce to the meeting the names of the officers elected.

ARTICLE VII

Management

SECTION 1. The President shall have general supervision of the affairs of the Association, shall preside at its meetings and those of the Executive Committee, and shall be a member *ex-officio* of every committee except the Nominating Committee.

SECTION 2. The Vice-Presidents, in order of seniority, shall preside at meetings in the absence of the President, and discharge his duties in case of a vacancy in the office.

SECTION 3. The Secretary-Treasurer, under the direction of the President and the Executive Committee, shall be the executive officer of the Association. He shall conduct the correspondence of the Association; record the proceedings of all meetings; collect and deposit all moneys due the Association; verify all bills and pay them when approved by the President or Executive Committee; make at each Annual Meeting a report of the accounts and membership of the Association; and perform such other duties as may be assigned to him by the Executive Committee.

SECTION 4. The Executive Committee shall manage the affairs of the Association, and shall have full power to control and regulate all matters not provided for in the Constitution. It shall act on applications for memberships; make appropriations for specific purposes; direct the care of the surplus funds of the Association; and audit the accounts of the Secretary-Treasurer.

SECTION 5. The Executive Committee shall publish the activities of the Association in a book to be known as the Annual Proceedings; but, subject to the action of the Association, it may withhold, in whole or in part, discussions, papers, or reports, the propriety or soundness of which is considered questionable.

SECTION 6. The Executive Committee shall have printed a Manual of Recommended Practice, in which shall be published the specifications and standards approved by the Association in accordance with Article X.

SECTION 7. The Executive Committee shall meet at such times and places as the President may direct, or five members may request in writing. Six members shall constitute a quorum.

ARTICLE VIII

Meetings

SECTION 1. An Annual Meeting, at which the officers shall be elected and all annual reports read, shall be held on the fourth Tuesday in January of each year, at ten o'clock A. M., at such place as the Association at the previous meeting may designate, provided, however, that if conditions arise which make it seem to the Executive Committee inadvisable to hold an Annual Meeting at the time or place designated, the Executive Committee shall have authority to designate another time or place for the meeting.

SECTION 2. Whenever the President may deem it necessary, or upon the written application of fifteen Corporate Members, he shall direct the Secretary-Treasurer to call a special meeting. The call for such a meeting shall state the time, place, and purpose of the meeting, and shall be mailed not less than thirty days prior to the date of the proposed meeting.

SECTION 3. Twenty Corporate Members shall constitute a quorum at any meeting of the Association.

SECTION 4. The order of business at the meetings of the Association shall be arranged by the Executive Committee, subject to addition or change by the votes of the majority of the members present.

ARTICLE IX

Amendments

SECTION 1. Proposed amendments to this Constitution must be offered in writing, signed by at least five Corporate Members, and forwarded to the Secretary-Treasurer not less than thirty days prior to the Annual Meeting. They shall be published with the notices for the meeting.

SECTION 2. Proposed amendments shall be in order for discussion at the Annual Meeting, and may be amended and adopted if two-thirds of the votes of the Corporate and Honorary Members present and voting are affirmative.

ARTICLE X

Adoption of Standards

SECTION 1. Any proposal for the approval of the Association of definitions, methods, nomenclature, specifications, standard construction or standard practice, or aimed at defining formally the position of the Association, shall have been made the subject of a study by a standing or special committee and embodied in a committee report published and distributed to the members of the Association not less than fifteen days prior to an Annual Meeting.

SECTION 2. The reports of committees embodying such proposals shall be in order for discussion at an Annual Meeting and shall be referred to letter ballot of the Association if a majority of the votes of the Corporate and Honorary Members present and voting is affirmative. Any proposal so submitted shall have the approval of the Association if a majority of the votes cast upon it by letter ballot is affirmative.

SECTION 3. The reports of committees embodying such proposals may be amended before submission to letter ballot if the votes of two-thirds of the Corporate and Honorary Members present and voting are affirmative; provided, however, that if, in the judgment of the committee submitting the report, any amendment so adopted affects underlying principles, that part of the report so affected shall be referred back to the committee for further consideration.

Past and Present Officers of the American Wood-Preservers' Association

Number	Year Elected	President	First Vice-President	Second Vice-President	Third Vice-President	Secretary-Treasurer
1st	1905	J. S. Baker	C. B. Lowry†	H. J. Whitmore†	F. A. Kummer*	C. W. Berry
2nd	1906	C. B. Lowry†	E. O. Faulkner	Edmund Christian*	David Allerton	C. W. Berry
3rd	1907	C. B. Lowry†	David Allerton	Walter Buehler	H. S. Valentine	C. W. Berry
4th	1908	Walter Buehler	C. B. Lowry†	David Allerton	H. S. Valentine	C. W. Berry
5th	1909	Walter Buehler	David Allerton	H. S. Valentine	H. M. Rollins	C. W. Berry
6th	1910	Walter Buehler	C. W. Berry	David Allerton	C. D. Chanute†	F. J. Angier
7th	1911	John T. Logan	Andrew Gibson	R. J. Calder	D. Burkhalter	F. J. Angier
8th	1912	E. A. Sterling	A. M. Smith	H. M. Rollins	G. B. Shipley	F. J. Angier
9th	1913	A. E. Larkin	J. H. Waterman	E. B. Fulks	Geo. E. Rex	F. J. Angier
10th	1914	Geo. E. Rex	Carl G. Crawford	R. S. Manley	F. B. Ridgway*	F. J. Angier
11th	1915	J. H. Waterman	H. S. Loud	Lowry Smith	F. D. Beal*	F. J. Angier
12th	1916	Carl G. Crawford	John Foley	M. K. Trumbull	--------	F. J. Angier
13th	1917	John Foley	M. K. Trumbull	J. B. Card	--------	F. J. Angier
14th	1918	M. K. Trumbull	J. B. Card	A. R. Joyce	--------	F. J. Angier
15th	1919	J. B. Card	A. R. Joyce	C. M. Taylor	--------	F. J. Angier
16th	1920	A. R. Joyce	C. M. Taylor	E. B. Fulks	--------	F. J. Angier
17th	1921	C. M. Taylor	F. J. Angier	H. S. Valentine	--------	Geo. M. Hunt

In 1915 the Executive Committee was increased to 11 members, the 6 additional members to serve from 1 to 3 years.

In 1916 the office of Third Vice-President was abolished.

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*Resigned
†Deceased

Meetings

Year	City	Hotel	Members Present	Visitors Present	Number of Pages in Proceedings	Number of Papers and Reports Presented
1905	New Orleans	St. Charles	15	No record	37	7
1906	Chicago	Palmer	16	No record	56	9
1907	Memphis	Baltimore	16	No record	64	10
1908	Kansas City	Gayoso	No record	No record	Not issued	--
1909	Chicago	Auditorium	--	100	141	12
1910	Chicago	Auditorium	24	74	190	14
1911	Chicago	Auditorium	50	70	302	20
1912	Chicago	Sherman	67	--	348	17
1913	Chicago	Sherman	83	36	525	22
1914	New Orleans	St. Charles	65	43	544	25
1915	Chicago	Congress	122	105	527	23
1916	Chicago	Sherman	115	89	432	31
1917	New York	Astor	100	133	538	26
1918	Chicago	Sherman	83	51	262	22
1919	St. Louis	Statler	104	141	309	30
1920	Chicago	Sherman	119	110	369	24
1921	San Francisco	St. Francis	74	58	590	34

LIST OF OFFICERS AND COMMITTEES

Officers

C. M. Taylor	*President*
F. J. Angier	*First Vice-President*
H. S. Valentine	*Second Vice-President*
Geo. M. Hunt	*Secretary-Treasurer*

Executive Committee

C. M. Taylor, *Chairman*

Business

H. S. Valentine, *Chairman*
R. J. Calder
John Foley
W. H. Grady
Geo. M. Hunt

Program

F. J. Angier, *Chairman*
H. E. Horrocks
A. R. Joyce
H. S. Sackett
Lowry Smith

Committee No. 2—Publications

C. C. Schnatterbeck, *Chairman*

Walter Buehler
W. F. H. Finke

Committee No. 3—Service Bureau Board

C. G. Crawford, *Chairman*

Walter Buehler
L. J. Colman
L. C. Drefahl
R. S. Manley
Grant B. Shipley
E. J. Stocking

Committee No. 4—Preservatives

A. L. Kammerer, *Chairman*

W. H. Fulweiler, *Vice-Chairman*
Ernest Bateman
F. G. Breyer
S. R. Church
L. C. Drefahl
J. H. Gibboney
F. W. Kroemer
K. M. Waddell
Galen Wood

Committee No. 5—Treatments

5-1-1 Ties—Fir

R. H. Rawson, *Chairman*
Charles Adams
R. S. Belcher
A. Gibson
E. G. Griggs
C. J. Hogue
A. C. Pestel
R. L. Wyman

5-2 Lumber—Car

W. J. Smith, *Chairman*
K. C. Barth
R. C. Clarke
E. E. Ingalls
C. E. Paul

5-5 Poles

R. F. Hosford, *Chairman*

5-8-1 Pressure Treatments

W. M. Carpenter, *Chairman*
C. D. Batson
E. E. Boehne
R. C. Eggleston
C. C. Fritz
A. H. Vorum

5-8-2 Non-Pressure Treatments

L. L. Hill, *Chairman*
C. H. Amadon
L. A. Furlong
Geo. M. Hunt
W. M. Leavitt
C. M. Sporley
W. K. Vanderpoel

5-9 Inspection

J. R. Keig, *Chairman*
J. M. Black
E. T. Davies
F. N. Graham
T. J. McGinty
Forrest S. Shinn
C. M. Tilley

Committee No. 6—Plant Operation

6-1 Peeling Ties

F. S. Pooler, *Chairman*
W. L. Bacon
Andrew Gibson
August Meyer
T. G. Townsend

6-2 Adzing, Boring and Perforating Layouts

D. W. Edwards, *Chairman*
J. H. Curry
R. H. Moore
Clyde Osborne

6-3 Car Loading

A. E. Larkin, *Chairman*
J. H. Bade
F. C. Krell
J. D. Latimer
M. M. Rabourn

6-5 Insurance

W. E. Doan, *Chairman*
J. B. Card
F. J. Hoxie
R. H. Moore
R. D. Parrott

6-6 Pressure Machinery

E. E. Alexander, *Chairman*
Wm. A. Cecil
J. H. Grow
W. E. Jackson
E. S. Park

6-7 Material—Handling

A. H. Onstad, *Chairman*
R. L. Allardyce
C. F. Ford
J. C. Williams

Committee No. 7—Utilization and Service

7-01 Economics

K. C. Barth, *Chairman*
A. W. Armstrong
R. A. Calvin
C. G. Crawford
L. B. Shipley
H. W. Woodruff, Jr.

7-1 Track

S. D. Cooper, *Chairman*
G. M. Davidson
G. C. Dixon
P. R. Hicks
O. C. Steinmayer
Earl Stimson
W. P. Wiltsee

7-3-1 and 7-3-2 Flooring and Paving

L. T. Ericson, *Chairman*

E. R. Dutton
S. D. Hicks
C. L. Humphreys
L. P. Kimball
Thos. A. Lawton
F. G. Marriott
K. J. Schmaelzle

San Francisco Bay Marine Piling Committee

F. D. Mattos, *Chairman*
W. C. Ball, *Secretary-Treasurer*
C. L. Hill, *Executive Officer*
H. A. Anderson
Ernest Bateman
A. M. Baxter
A. A. Brown
H. J. Brunnier
C. E. Cortes
*H. O. Demerrit
*C. E. Derleth
*W. W. DeWinton
*H. F. Faull
*Emanuel Fritz
*H. H. Hall
*H. K. Heck
*G. H. Hicks
*Lieut. Allen Hoar
*Howard C. Holmes
Geo. M. Hunt
*W. J. Hunter
W. M. Jaekle
*Capt. F. B. Jones
L. D. Jurs
W. H. Kirkbride
C. A. Kofoid
*C. A. Kupfer
*Lieut. C. L. Macrae
Chas. R. McCormick
*Jerome Newman
*H. S. Pond
R. H. Rawson
*G. W. Rear
*Capt. H. W. Rhodes
*W. T. Richards
*F. B. Smith
*O. K. Smith
R. G. Smith
O. R. West
F. G. White
J. W. Williams

*Honorary Members

NOTICE—The Association is not responsible as a body for the opinions expressed by individuals.

LIST OF MEMBERS

(Complete to July 1, 1921)

c-Corporate. a-Associate. p-Probate. h-Honorary.

Figures indicate serial number of Membership Certificate

384	c	ADAMS, CHARLES	Supt. Wood Preserving Works, Southern Pacific Railroad, Cottage Grove, Oregon.
183	c	ALEXANDER, E. E.	Supervisor of Plants, Baltimore and Ohio Railroad, Green Spring, W. Va.
29	c	ALLARDYCE, R. L.	Gen. Supt., International Creosoting and Construction Co., Texarkana, Texas.
360	a	ALLEN, E. J.	Ties and Lumber, 32 Broadway, New York City.
21	h	ALLERTON, DAVID	Winters, Cal.
443	c	ALMON, W. D.	Cairo, Ill.
569	c	AMADON, C. H.	In Charge Inspection, Western Electric Co., 463 West St., New York City. (1921).
554	c	AMIS, J. C.	Chief Engr., Detroit and Mackinac Railway, East Tawas, Mich. (1921).
531	c	ANDERSON, HARVEY A.	Ass't Engr., Southern Pacific Co., 165 Broadway, New York City.
405	c	ANDREWS, HOWARD	Pres., Nashville Tie Co., Nashville, Tenn.
1	c	(Charter) ANGIER, F. J.	Supt. Timber Preservation, Baltimore and Ohio Railroad, Baltimore, Md.
407	c	ARMSTRONG, ARTHUR W.,	Sec'y-Treas., Ayer and Lord Tie Co., Chicago, Ill.
494	c	ARMSTRONG, WESTROPP	Sales Mgr., Creosoted Block Paving Co., Ltd., Toronto, Canada.
475	c	ASHBY, H. N.	Mfg. Dept., Long-Bell Lumber Co., Kansas City, Mo.
550	c	AUSTIN, H. E.	Chief Engr., American Creosoting Co., Louisville, Ky. (1921).
547	c	BABCOCK, E. B.	Chief Inspector Pacific Northwest, R. W. Hunt and Co., 410 Lyon Bldg., Seattle, Wash. (1921).
105	c	BACON, W. L.	Supt. Tie Treating Plant, Chicago and Northwestern Railway, Escanaba Mich.
411	c	BADE, J. H.	Ass't Supt., Central Creosoting Co., North Bend, Ohio.
3	h	(Charter) BAKER, J. S.	Oaklawn Sugar Co., Ltd., Franklin, La.
571	c	BALL, W. C.	Sales Mgr., Chas. R. McCormick Co., 900 Fife Bldg., San Francisco, Cal. (1921).
410	c	BARBER, F. A.	Indiana Zinc Creosoting Co., Terre Haute, Ind.
379	a	BARTH, KURT C.	Technical Representative, The Barrett Co., 17 Battery Place, New York City.
167	c	BATEMAN, ERNEST	Chemist in Forest Products, Forest Products Laboratory, Madison, Wis.
88	c	BATSON, C. D.	Mgr., Republic Creosoting Co., Mobile, Ala.
460	c	BAXTER, ALFRED M.	Care J. H. Baxter & Co., 702 National Bank Bldg., San Francisco, Cal.
198	c	BECKER, A. C.	9 Monument Avenue, Dayton, Ohio.
145	c	BELCHER, R. S.	Mgr., Treating Plants, Atchison, Topeka and Sante Fe Railway, Topeka, Kans.
479	c	BELL, H. C.	Supt. Tie Treating Plant, Norfolk and Western Railway Co., Roanoke, Va.
144	c	BERK, P. F.	Chemical Mfr., F. W. Berk & Co., Ltd., 1 Fenchurch Ave., London, England.
444	a	BERMINGHAM, EDW.	Sales Dept.. International Coal Products Corporation, 24 Broad St., New York City.
207	a	BERNUTH, OSCAR	Pres., Bernuth, Lembcke Co., Inc., 171 Madison Avenue, New York City.
5	h	(Charter) BERRY, C. W.	Care A. G. Shaver, Room 857 Gas Bldg., Chicago, Ill.
300	c	BLACK, JAMES M.	Forestry Dept., Pennsylvania System, Box 83, Connellsville, Pa.
561	a	BLACKALL, ROB'T H.	Mfr. of Railway Supplies, 1305 Farmers' Bank Bldg., Pittsburgh, Pa. (1921).
537	a	BLASSINGHAM, M. T.	Pres. and Treas., M. T. Blassingham & Co., Inc., Norfolk, Va.
22	c	BOEHNE, E. E.	Mgr. Sales Dept., International Creosoting & Construction Co., Galveston, Texas.
503	c	BOLSOVER, GUY	Civil Eng., London and Northwestern Railway, Euston, London N. W. 1, England.
477	c	BOOK, J. E.	Supt., Pacific Creosoting Co., Creosote, Kitsap County, Wash.
244	c	BOWSER, E. H.	Supt. Timber Dept., Illinois Central Railroad, Memphis, Tenn.
447	c	BOYER, LOUIS	Electrical Eng., Etablissements Gaillard, 7 F, Rue Sebastapol, Beziers, France.
563	a	BRADLEY, MARK	Sales Mgr., Monsanto Chemical Works, St. Louis, Mo. (1921).
280	p	BRENNAN, T. S.	Lumber Inspr., Atchison, Topeka and Santa Fe Railway, 1119 L. C. Smith Bldg., Seattle, Wash.

368 a BREYER, FRANK G.......Chief of Research Dept., New Jersey Zinc Co., Palmerton, Pa.
406 c BRIGGS, Z. M...............Ass't Eng. Maintenance, Pennsylvania System, Pittsburgh, Pa.
301 c BRIGHT, EDGAR W.........Pres., Mass. Lumber and Creosoting Co., 104 Milk St., Boston, Mass.
507 c BROWN, A. A...............Construction Eng., California and Hawaiian Sugar Refining Co., Crockett, Cal.
230 c BROWN, NELSON C.......Care American Woods Export Association, Room 506, 30 Church St., New York City.
377 a BROWN, S. K...............Vice Pres. & Gen. Mgr., American Tie and Timber Co., 11 Broadway, New York City.
499 c BRUNNIER, H. J............Designing and Consulting Structural Engr., 312 Sharon Bldg., San Francisco, Cal.
408 c BRYAN, GORDON............Florida Lumber and Crate Co., Kissimee, Fla.
23 c BUEHLER, WALTER.......Engr. of Wood Preservation, The Barrett Co., 17 Battery Place, New York City.
24 c BURKHALTER, D............Supt., Indiana Creosoting Co., Bloomington, Ind.
472 c BURNES, JOHN D..........Care, Page and Hill Co., 814 Plymouth Bldg., Minneapolis, Minn.
546 c BUSH, H. O.................Lumber and Tie Inspector, Erie Railroad, 50 Church St., New York City (1921).

83 a CABOT, SAMUEL............Manufacturing Chemist, 141 Milk St., Boston, Mass.
30 c CALDER, R. J...............Sec'y-Treas., International Creosoting & Construction Co., Galveston, Texas.
388 c CALVIN, R. A...............Sales Mgr., The Kettle River Co., Madison, Ill.
190 c CAMPBELL, J. H............Chemical Engr., R. W. Hunt & Co., 2200 Insurance Exchange, Chicago, Ill.
43 c CARD, J. B...................Pres., Central Creosoting Co., 111 W. Washington, St., Chicago, Ill.
433 c CARMAN, C. EDW..........Indiana Tie Company, Joppa, Ill.
352 c CARPENTER, W. M.........Vice-Pres., American Line Materials Co., McCormick Bldg., Chicago, Ill.
276 c CECIL, WM. A...............Wood Preserving Engr., Indiana Tie Company, Evansville, Ind.
476 c CHADBOURNE, B...........Office Mgr., Pacific Creosoting Co., 204 Northern Life Bldg., Seattle, Wash.
392 c CHADWICK, CHAS. S......Gen. Mgr., Eppinger and Russell Co., 165 Broadway, New York City.
302 c CHAPIN, E. T...............Pres., E. T. Chapin Co., Columbia Bldg., Spokane, Wash.
69 c CHERRINGTON, F. W.....Dir. Engr. Sales, The Jennison-Wright Co., Toledo, Ohio.
372 p CHILCOAT, G. W...........Foreman, Mt. Union Wood Preserving Plant, Pennsylvania System, Mt. Union, Pa.
57 a CHURCH, SUMNER, R.....Mgr. Tar and Oil Dept., The Barrett Co., 17 Battery Place, New York City.
560 c CLARK, E. L.................Pres., Valentine-Clark Co., 510 Peyton Bldg., Spokane, Wash. (1921).
386 c CLARKE, ROY C............Treating Inspr., Pittsburgh and Lake Erie Railroad, P. & L. E. Terminal Bldg., Pittsburgh, Pa.
165 c CLARKE, G. S................U. S. Army.
319 p CLEMENTS, C. M. ....Supt. Plant, Railway Tie Treating Co., Inc., Box 198, Lancaster, Pa.
385 a CLIFFORD, W. E............Forest Products Chemical Co., Memphis, Tenn.
174 a CLIFTON, W. H.............Vice-Pres., Anguera Lumber and Tie Co., 1101 Conway Bldg., Chicago, Ill.
365 c COLLINS, EVERELL S....347 Pittock Block, Portland, Oregon.
397 c COLLSTROP, A...............Chairman, R. Collstrop, Ltd., Copenhagen, Denmark.
67 c COLMAN, GEO. A...........Colman Creosoting Works, Colman Bldg., Seattle, Wash.
553 c COLMAN, L. J...............Pres., Colman Creosoting Works, Seattle Wash. (1921).
493 c CONDON, H. R...............Ass't Forester, Pennsylvania System, 613 Emergency Fleet Bldg., Philadelphia, Pa.
536 a COOK, WM. P...............Wm. P. Cook & Co., 79-85 Wall St., New York City.
535 a COONEY, CARROLL T.....Sec'y-Treas., Cooney, Eckstein & Co., 302 Broadway, New York City.
221 c COOPER, S. D...............Ass't Mgr. Treating Plants, Atchison, Topeka and Santa Fe Railway, Topeka, Kans.
508 c CORTES, CARLOS E.......Construction Engr., Shell Company, Martinez, Cal.
31 c CRAWFORD, CARL G. ....Vice Pres., American Creosoting Co., Louisville, Ky.
452 c CURRY, J. H.................Boring Machine Foreman, Atchison, Topeka and Santa Fe Railway, National City, Cal.
515 c CURTIN, MATTHEW J.....Tie and Timber Agent, Boston Elevated Ry. Co., Boston, Mass.

25 c DAVIDSON, G. M............Chemist & Engr. of Tests, Chicago and Northwestern Railroad, Chicago, Ill.

148	c	DAVIES, E. T.	Inspector, City Engineer's Office, 125 Bryant Ave. N., Minneapolis, Minn.
510	a	DAVIS, H. E.	Sales Div'n Mgr., The Grasselli Chemical Co., Cleveland, Ohio.
524	a	DAVIS, JOHN W.	Gen. Supt., American Tar Products Co., 208 South LaSalle St., Chicago.
557	c	DAWSON, THOS W.	Chief Engr., H. C. Frick Coke Co., Scottdale, Pa. (1921).
84	c	DeCEW, J. A.	Chem. Engr., 501 Fifth Ave., New York City.
530	c	DEUTSCH, MARGARET F.	Statistician, Forest Products Laboratory, Madison, Wis.
228	c	DIXON, G. C.	Tie Treating Inspr., C. C. C. & St. L. Railway, Indianapolis, Ind.
64	c	DIXON, J. H.	Burd Ring Sales Co. of Canada, 322 McIntyre Block, Winnipeg, Man., Canada.
424	c	DOAN, WM. E.	Vice Pres., Canada Creosoting Co., Toronto, Canada.
290	c	DOW, ALLAN W.	Consulting Engr., Dow & Smith, 131 E. 23rd St., New York City.
121	c	DRAPER, ERNEST G.	Pres., American Creosoting Co. of New Jersey, 17 Battery Place, New York City.
166	a	DREFAHL, LOUIS C.	Chemist, Grasselli Chemical Company, Cleveland, Ohio.
383	c	DRESSER, GEO. L.	Sales Engr., The Jennison-Wright Co., Albany, N. Y.
178	c	DUNSTAN, J. H.	Supt., Southern Creosoting Co., Slidell, La.
211	c	DURHAM, J. H.	Vice Pres., American Creosoting Co., Louisville, Ky.
322	c	DUTTON, ELLIS R.	Ass't City Engr., Minneapolis, Minn.
202	a	EASTWICK, CHAS. H.	Pres., Northeastern Co., 6 Beacon St., Boston, Mass.
418	a	EDWARDS, D. W.	Representative, Greenlee Bros. & Co., Takoma Park, Washington, D C.
481	c	EGGLESTON, R. C.	Forester, American Telephone & Telegraph Co., 195 Broadway, New York City.
393	c	ELAM, WM.	Store Dept., Missouri, Kansas and Texas Railway, Parsons, Kansas.
275	c	EMERSON, HARRINGTON	Pres., The Emerson Co., 30 Church St., New York City.
577	c	ENRIGHT, F. M.	Pres., Creo-Fir Wood Block Paving Co., 138 N. LaSalle St., Chicago, Ill. (1921).
163	c	ERICSON, L. T.	Chief Engr., The Jennison-Wright Co., Toledo, Ohio.
341	c	FAIRLEY. ROBT. H.	Plant Supt., St. Helens Creosoting Co., St. Helens, Oregon.
451	c	FALCONER, R. C.	Chief Engr., The Erie Railroad, 50 Church St., New York City.
158	c	FANT, A. E.	Pres., Gulfport Creosoting Co., Gulfport, Miss.
9	h	(Charter) FAULKNER, E. O.	Mgr. Tie & Timber Dept., Atchison, Topeka and Santa Fe Railway, Los Angeles, Cal.
544	c	FAYLOR, C. E.	Union Cedar Co., 1501-5 2nd National Bank Bldg., Toledo, Ohio. (1921).
239	c	FERGUSSON, HUBERT	Gen. Mgr., Burt, Boulton & Haywood, Ltd., Prince Regent's Wharf, Silverton, Victoria Docks, London, England.
237	c	FINKE, W. F. H.	Tie and Timber Agent, Southern Railroad, Washington, D. C.
62	c	FISHER, WM. A.	Bernuth Lembcke Co., Inc., 171 Madison Ave., New York City.
308	a	FOERSTERLING, HANS	The Abor Farm, Jamesburg, N. J.
77	c	FOLEY, JOHN	Forester, Pennsylvania System, 618 Emergency Fleet Bldg., Philadelphia, Pa.
106	c	FORD, C. F.	Supt. Tie & Timber Department, Chicago, Rock Island and Pacific Ry., Chicago.
318	c	FOWLER, J. W.	Sales Rep., Hoggson Brothers, 485 Fifth Avenue, New York City.
568	a	FOX, M. J.	Sec'y-Treas., Von-Platen-Fox Co., Iron Mountain, Mich. (1921).
491	c	FRANCE, R. L.	Lumber and Fuel Agent, Southern Pacific Co., San Francisco, Cal.
117	c	FREY, GEO. W.	Gen. Mgr., Compressed Wood Preserving Co., 4665 Spring Grove Ave., Cincinnati, Ohio.
333	c	FRISTOE, J. W.	Pres., T. J. Moss Tie Co., St. Louis, Mo.
347	c	FRITZ, C. C.	Treating Engr., Long-Bell Lumber Co., Kansas City, Mo.
454	c	FRYE, RALPH K.	Mgr., Post, Pole and Paving Block Sales, Long-Bell Lumber Co., Kansas City, Mo.
38	c	FULKS, E. B.	Pres., Arkansas Zinc Co., St. Louis, Mo
160	a	FULWEILER, W. H.	Chemist, United Gas Improvement Co., Philadelphia, Pa.
306	a	FURLONG, L. A.	Vice Pres., Walsh Tie Co., 910-914 Security Bldg., Minneapolis, Minn.
456	c	GARLAND, FRANK J.	Selling Agent, St. Helens Creosoting Co., San Diego, Cal.
44	a	GERHARD, H. H.	Pres., C. A. Wood Preserver Co., St. Louis, Mo.
482	c	GIBBONEY, J. H.	Chief Chemist, Norfolk and Western Railway, Roanoke, Va.

39	c	GIBSON, ANDREW	Supt. Timber Preservation, Northern Pacific Railroad, Brainerd, Minn.
180	a	GIBSON, W. C.	Sales Mgr., Plate and Tank Dept., Graver Corporation, E. Chicago, Ind.
512	a	GOLDEN, W. J.	Gen. Mgr., By-Products Steel Corporation, Weirton, W. Va.
56	c	GOLTRA, W. F.	Pres., W. F. Goltra Tie Co., Cleveland, Ohio.
288	c	GOSLINE, C. E.	Roadmaster, Delaware, Lackawanna and Western Railroad, Hoboken, N. J.
277	c	GOSS, O. P. M.	Consulting Timber Engr., Goss & Rawson, 504 White Bldg., Seattle, Wash.
243	c	GRADY, W. H.	Gen. Supt., American Creosoting Co., 401 West Main St., Louisville, Ky.
100	c	GRAHAM, FLOYD N.	Chief Timber Inspr., Chicago Great Western, Chicago, Ill.
445	c	GRAHAM, R. A.	Supervisor of Treatment, Missouri Pacific, 551 Veronica Ave., E. St. Louis, Ill.
522	a	GRAMM, CHAS. WM.	Salesman, Ernst Zobel Co., 2nd Ave. and 10th St., Brooklyn, N. Y.
539	c	GRANT, J. D.	Vice Pres., Southern Creosoting Co., Slidell, La.
486	c	GREENE, C. W.	Timber Treatment Engr., New York Central Railroad, 581 Durango Drive, Toledo, Ohio.
548	a	GREENEBAUM, MILTON	Vice Pres., Kern Commercial Co., 114 Liberty St., New York City. (1921).
559	a	GREIG, WM. R.	Salesman, Paraffine Companies, 34 First Street, San Francisco, Cal. (1921).
334	c	GRIGGS, E. G.	Pres., St. Paul and Tacoma Lumber Co., Tacoma, Wash.
72	a	GROW. J. H.	Engr., Wood Preservation, Allis-Chalmers Mfg. Co., Milwaukee, Wis.
534	a	GUTSCHOW, PAUL	Mgr., R. Bardewyck, 150 Nassau St., New York City.
231	c	HAGGANDER, G. A.	Ass't Bridge Engr., Chicago, Burlington and Quincy Railroad, Chicago.
442	a	HAMILTON, C. L.	Sec'y, Weyerhaeuser Forest Products, St. Paul, Minn.
195	c	HAMILTON, F. P.	Creosoted Materials Co., Inc., New Orleans, La.
562	c	HAMILTON, R. M.	Gen. Foreman, Central Creosoting Co., 7228 Lower River Road, Fern Bank, Cincinnati, Ohio (1921).
473	c	HARPER, LEWIS H.	Supt. Creosote Plant, Central of Georgia Railway, Crump's Park, Ga.
425	c	HARRELL, E. H.	E. H. Harrell Co., Houston, Texas.
529	c	HARRIS, GEO. H.	Gen. Supt., San Francisco-Oakland Terminal Railways, Oakland, Cal.
187	c	HARRIS, PAGE	Vice Pres., National Lumber & Creosoting Co., Houston, Texas.
123	a	HARTLEY, C. H.	Gen. Mgr., Wisconsin and Northern Railroad, Appleton, Wis.
82	c	HARTMAN, E. F.	Pres., Protexol Corporation, 34 Barclay St., New York City.
53	a	HAWKES, A. W.	Vice Pres., General Chemical Co., 25 Broad St., New York City.
527	c	HEIM, A. L.	Engr. in Forest Products, Forest Products Laboratory, Madison, Wis.
236	c	HELSON, J. R.	Supt., Watkins Creosoting Co., Metropolis, Ill.
521	a	HENDERSON, C. T.	Sales Mgr., Great Western Electro Chemical Co., San Francisco, Cal.
108	c	HENDRICKS, V. K.	131 North 8th St., Terre Haute, Ind.
422	a	HENDRICKS, W. HOMER	Gen. Sales Mgr., New Jersey Zinc Co., 160 Front St., New York City.
335	c	HERMANN, GEO. E.	Mgr., Vancouver Creosoting Co., Ltd., North Vancouver, B. C.
75	c	HESS, LAWRENCE E.	Ass't Supt., Republic Creosoting Co., Indianapolis, Ind.
370	c	HICKS, P. R.	Secretary-Manager, Service Bureau, A. W. P. A., 1146 Otis Bldg., Chicago, Ill.
409	a	HICKS, S. D.	Sales Mgr., The Rodd Co., Pittsburgh, Pa.
518	c	HILL, C. L.	U. S. Forest Service, Ferry Bldg., San Francisco, Cal.
328	c	HILL, L. L.	Sec'y, Page and Hill Co., Minneapolis, Minn.
552	a	HINCKLEY, G. W.	Pres., Geo. W. Hinckley & Co., 63 Wall St., New York City (1921).
449	c	HOGUE, CHESTER JAMES	Engr. in Forest Products, West Coast Lumbermen's Ass'n, 3784 Grand Central Terminal, New York City.
364	c	HOPKINS. H. W.	Lumber Inspr., Pennsylvania System, Jacksonville, Fla.
179	c	HORROCKS, H. E.	Mgr., Pacific Creosoting Co., Seattle, Wash.
359	c	HOSFORD, R. F.	Telephone Engr., American Telephone and Telegraph Co., 195 Broadway, New York City.
578	c	HOWE, PAUL J.	Construction Engr., Western Union Telegraph Co., 195 Broadway, New York City.
193	c	HOWSON, E. T.	Editor, "Railway Maintenance Engineer," Transportation Bldg., Chicago, Ill.
350	c	HOXIE, F. J.	Insurance Engineer, Associated Factory Mutual Fire Insurance Companies, 31 Milk St., Boston, Mass.

342	c	HOYT, H. B.	Supt. Timber Preservation Plant, Buffalo, Rochester and Pittsburgh Railway, Bradford, Pa.
448	c	HOYT, WARREN EDW.	Gen. Mgr., Monongahela Wood Preserving Co., 917 Citizens Bldg., Cleveland, Ohio.
498	c	HUMPHREYS, C. L.	Paving Contractor, Ionia, Mich.
265	c	HUNT, GEO. M.	Chemist, Forest Products Laboratory, Madison, Wis.
376	c	INGALLS, EDMUND E.	Chemist, Chicago, Burlington and Quincy Railroad, 144 Sumner St., Galesburg, Ill.
356	c	ISAACS, JOHN D.	Consulting Engr., Southern Pacific Co., 165 Broadway, New York City.
252	c	JACKSON, W. E.	Supt., Texas Tie and Lumber Preserving Co., Somerville, Texas.
489	c	JAEKLE, W. M.	Asst. Engr. M. of Way and Struct., Southern Pacific, San Francisco, Cal.
413	a	JAHNCKE, WALTER F.	Pres., The Reeves Co., New Orleans, La.
124	c	JENNISON, H. G.	Pres., The Jennison-Wright Co., Toledo, O.
260	c	JOHNSON, J. A.	Supt. Tie Preserving Plant, Union Pacific Railroad, Box 303, Laramie, Wyoming.
440	a	JOHNSON, T. P.	
401	a	JORDAN, J. H.	Sales Div. Mgr., Grasselli Chemical Co., Cleveland, Ohio.
66	c	JOYCE, A. R.	Joyce-Watkins Co., 332 S. Michigan Ave., Chicago, Ill.
147	c	JUDGE, F. B.	4555 Ridge Ave., Glen Morris, Long Island, N. Y.
532	a	JURS, LOUIS D.	Chief Engr., Associated Oil Co., 817 Sharon Bldg., San Francisco, Cal.
205	c	KAMMERER, A. L.	Consulting Timber Engr., von Schrenk & Kammerer, Tower Grove and Flad Avenues, St. Louis, Mo.
467	a	KEHOE, H. B.	Salesman, Gillis & Co., Heyworth Bldg, Chicago, Ill.
222	c	KEIG, J. R.	Gen. Tie and Timber Inspr., Atchison, Topeka and Santa Fe Railway, 925 Ry. Exchange Bldg., Chicago, Ill.
528	c	KELLEHER, W. J.	Gen. Mgr. Southern Creosoting Co., Ltd., Slidell, La.
315	h	KENDRICK, J. W.	Consulting Engr., 1733 Lytton Bldg., Chicago, Ill.
403	c	KENNEDY, LEE T.	Inspr. of Treatment, Texas and Pacific and International and Great Northern Railroads, Houston, Texas.
281	c	KENT, A. S.	Chief Engr., Chicago, Indianapolis and Louisville Railroad, Chicago, Ill.
492	c	KIMBALL, L. P.	Engr. of Buildings, Baltimore and Ohio Railroad, Baltimore, Md.
514	a	KINKEL, REVERE P.	Works Mgr., By-Products Steel Corporation, Weirton, W. Va.
541	a	KINNEY, NORMAN B.	Pres., The Kinney Co., 17 W. 42nd St., New York City (1921).
431	a	KINSMAN, J. WARREN	DuPont Chemical Works, Wilmington, Del.
574	a	KINZEL, L. K.	Kinzel Lumber Co., Merrill, Wis. (1921).
488	c	KIRKBRIDE, W. H.	Engr. of Maint., Southern Pacific Co., San Francisco, Cal.
502	c	KISTLER, L. W.	Chemist, Santa Fe Tie and Lumber Preserving Co., Somerville, Texas.
542	c	KITTLE, CARLTON L.	Treating Inspector, Baltimore and Ohio Railroad, North Bend, Ohio (1921).
566	c	KNEELAND, R. E.	Kettle River Company, Madison, Ill. (1921).
487	c	KRELL, F. C.	Asst. Forester, Pennsylvania System, 613 Emergency Fleet Bldg., Philadelphia, Pa.
201	c	KROEMER, F. W.	Bernuth Lembcke Co., Inc., 421 W. 22nd Ave., Houston, Texas.
519	c	KOFOID, CHAS. A.	Prof. of Zoology, University of California, Berkeley, Cal.
162	c	KUEHN, A. L.	Vice Pres., American Creosoting Company, Louisville, Ky.
20	c	LABROT, S. W.	Pres., American Creosote Works, New Orleans, La.
59	c	LARKIN, A. E.	Mgr., Republic Creosoting Company, Minneapolis, Minn.
461	c	LATIMER, J. D.	International Creosoting & Construction Company, Galveston, Texas.
317	a	LATTIMORE, C. H.	Pres., Creosoted Block Paving Co., Canadian Pacific Railroad Bldg., Toronto, Can.
96	c	LAWSON, W. W.	Supt. Plant, National Lumber and Creosoting Co., 336 Railway Exchange Bldg., Kansas City, Mo.
394	c	LAWTON, THOS. A.	Sec'y, American Creosoting Co., 17 Battery Place, New York City.
538	c	LEAVITT, W. M.	Western Cedar Pole Preservers, 547 Peyton Bldg., Spokane, Wash.
328	a	LEE, ROBERT E.	Pres., Hobart Lee Tie Co., Springfield, Mo.
40	a	LEMBCKE, G. A.	Sec'y-Treas., Bernuth Lembcke Co., 171 Madison Ave., New York City.
517	a	LEVERETT, W. H.	Supt., National Zinc Co., Kansas City, Kans.
110	a	LEWIS, F. J.	Pres., F. J. Lewis Mfg. Co., 2500 S. Robey St., Chicago Ill.

118 a LEWIS, W. H. ------------Vice Pres., F. J. Lewis Mfg. Co., 2500 S. Robey St., Chicago, Ill.
583 c LINDSLEY, E. A. ---------Vice Pres., & Gen. Mgr., Western Wood Preserving Co., Spokane, Wash.
199 a LOCKETT, A. M. ----------Pres., A. M. Lockett & Co., New Orleans, La.
12 c (Charter) LOGAN, JOHN T.--Pres., National Lumber and Creosoting Co., Texarkana, Ark.
242 c LOOK, RICHARD V. ------Pres., Canada Creosoting Co., Toronto, Canada.
112 c LORD, RUSSELL ---------Pres., Ayer and Lord Tie Co., 1515 Railway Exchange Bldg., Chicago, Ill.
61 c LOUD, H. S. --------------Vice Pres., Railway Tie Treating Co., 165 Broadway, New York City.

458 a MANDENBERG, EDMUND C., Forester, The Barrett Co., 6210 Justine St. Chicago, Ill.
345 p MANION, KERON --------Asst., Supt., American Creosoting Co. of New Jersey, Newark, N. J.
41 c MANLEY, R. S. -----------Pres., Creosoted Materials Co., 301 Queen and Crescent Bldg., New Orleans, La.
263 c MARRIOTT, F. G. ---------Engr. of Tests, Dept. of Works, Toronto, Canada.
250 c MARTIN, F. R. -----------Mgr. Post and Pole Dept., Long-Bell Lumber Co., Marion, Ill.
336 a MARTIN, JAS. R. ---------Vice Pres., Western Silo Co., Des Moines, Ia.
137 c MATTOS, F. D. -----------Mgr. Treating Plants, Southern Pacific Co., West Oakland, Cal.
52 c McARDLE, FRANK -------Supt. Tie Plant, Indiana Zinc Creosoting Co., Terre Haute, Ind.
453 c McCORMICK, CHAS. R. ----Pres., Chas. R. McCormick Co., Fife Bldg., San Francisco, Cal.
555 a McCORMICK, H. F. -------Mgr., St. Helens Lumber Co., St. Helens, Ore. (1921).
415 c McCRORY, FRANK -------Chief Tie Inspr., Chicago, Rock Island & Pacific Railroad, Little Rock, Ark.
441 c McELHINNEY, H. G. -----Gen. Supt., The Kettle River Co., Madison, Ill.
434 c McGINTY, THOMAS J. ----Treating Inspr., Pennsylvania System, 1006 Century Bldg., St. Louis, Mo.
428 a McGREW, CHAS. L. -------Pres., Western States Lumber Co., Kansas City, Mo.
464 c McKEE, R. E. -------------Long-Bell Lumber Co., Kansas City, Mo.
113 c MEREDITH, W. C. --------Supt., Southern Wood Preserving Co., Atlanta, Ga.
419 c MERRITT, H. T. -----------Supt., Indiana Tie Co., 904 Citizens' Bank Bldg., Evansville, Ind.
496 a MILLER, DAVID B. -------c/o Crowell & Murray, Perry-Payne Bldg., Cleveland, Ohio.
71 c MEYER, AUGUST ----------Walsh Tie Co., 910 Security Bldg., Minneapolis, Minn.
474 c MEYER, E. H. ------------Vice Pres., St. Helens Creosoting Co., 913 Yeon Bldg., Portland, Oregon.
501 a MOODY, WALTER I., JR.--Ass't Sec'y, Denver Metals Co., Denver, Colo.
520 a MOORE, GRANVILLE ----Pres., Metals & Chemicals Extraction Corporation, San Francisco, Cal.
254 c MOORE, Robt. H. ----------Gen. Supt., Canada Creosoting Co., 1 King St. E., Toronto, Ontario.
576 c MORIER, L. E. -----------In Charge Pole Treating Plant, Naugle Pole and Tie Co., 55 Wabash Ave., Chicago, Ill. (1921).
545 c MORRIS, FRED N. --------Sales Mgr., Union Cedar Co., 1501-5 Second National Bank Bldg., Toledo, Ohio (1921).
114 c MOSES, L. B. -------------Mgr., Lumbermen's Rail and Equipment Bureau, Chicago, Ill.
309 c MURCHIE, W. E. ---------Cross, Austin, & Ireland Lumber Co., 1246 Grand St., Brooklyn, N. Y.
351 c MURPHY, WM. B. -------Chief Chemist, F. J. Lewis Mfg. Co., 2500 S. Robey St., Chicago, Ill.
402 c MURRAY, D. L. -----------Supt., Atchison, Topeka and Santa Fe Treating Plant, Albuquerque, N. M.
307 p MYERLY, J. R. -----------Treating Engr., Baltimore and Ohio Railroad, Green Spring, W. Va.

50 c NEWTON, H. M. ----------Vice Pres. & Gen. Mgr., Midland Creosoting Co., Granite City, Ill.
416 a NITCHIE, CHAS. C. ------Chemist, Mineral Point Zinc Co., Depue, Ill.
283 a NIXON, E. A. -------------Vice Pres., Western Tie & Timber Co., St. Louis, Mo.
314 a NIXON, WARREN C. -----Vice Pres., Western Tie & Timber Co., St. Louis, Mo.

455 c OLSON, JOHN ------------Selling Agent, St. Helens Creosoting Co., 533 Van Nuys Bldg., Los Angeles, Cal.
570 a ONSTAD, A. H. -----------Engr. and Mill Architect, Weyerhaeuser Timber Co., Box 1607, Tacoma, Wash. (1921).
209 c OSBORNE, CLYDE --------Plant Mgr., St. Helens Creosoting Co., St. Helens, Oregon.

253 c PARK, ERNEST S. --------Sales Eng., Ohio Wood Preserving Co., 1053 Century Bldg., Pittsburgh, Pa.
26 c PARMINTER, L. I. --------Fort Morgan, Colo.
268 c PARROTT, R. D. ----------Pres. & Gen. Mgr., Atlantic Creosoting Co., Norfolk, Va.

404	c	PAUL, C. E.	Prof. of Mechanics, Armour Institute of Technology, Chicago, Ill.
271	c	PAUL, H. A.	Treating Inspr., Chicago, Rock Island and Pacific Railroad, Tie Plant, Ark.
343	c	PEARSON, RALPH S.	Forest Economist, Forest Research Institute and College, Dehra Dun, U. P., India.
450	c	PEIMBERT, ANGEL	Chief Engr., National Railways of Mexico, Colonia Station, Mexico City, Mex.
436	c	PELZ, E. M.	Treatment Inspr., Chicago, Milwaukee and St. Paul Railway, Evansville, Ind.
395	c	PENNEY, JOHN S.	T. J. Moss Tie Co., St. Louis, Mo.
462	c	PEPPLER, R. A.	Supt., Pittsburgh Wood Preserving Co., Adelaide, Pa.
348	c	PERSHALL, E. E.	Vice Pres., T. J. Moss Tie Co., St. Louis, Mo.
191	c	PESTEL, A. C.	Supt. Tie Treating Plant, Oregon-Washington Railroad and Navigation Co., Wyeth, Oregon.
457	a	PIERCE, HENRY B.	Pierce Fluor Spar Co., Golconda, Ill.
115	c	POOLER, F. S.	Tie Agent, Chicago, Milwaukee and St. Paul Railway, Chicago, Ill.
500	c	POST, C. F.	Ass't Purch. Agt., Western Pacific Railroad, Mills Bldg., San Francisco, Cal.
511	a	POTTER, H. R.	Salesman, Potter-Coyle, Bessemer Bldg., Pittsburgh, Pa.
505	c	POUX, R. R.	Inspector, Erie Railroad, Meadville, Pa.
446	c	PUSINELLI, JOHN A.	Treatment Inspr., Atchison, Topeka and Santa Fe Railway, Carbondale, Ill.
509	c	POWELL, F. C.	Mgr., Republic Creosoting Co., Seattle, Wash.
396	a	QUEENY, JOHN F.	Pres., Monsanto Chemical Works, 1800 S. Second St., St. Louis, Mo.
380	c	RABOURN, M. M.	Treating Inspr., Baltimore and Ohio Railroad, North Bend, Ohio.
261	c	RAWSON, R. H.	Goss and Rawson, 1124 Yeon Bldg., Portland, Oregon.
331	c	RAY, JOHN R.	438 S. Galvez St., New Orleans, La.
155	c	RECORD, S. J.	Prof. of Forest Products, Yale University, New Haven, Conn.
54	c	REX, GEO. E.	Vice Pres., National Lumber & Creosoting Co., 1734 Strong Ave., Topeka, Kans.
526	a	RHODES, E. O.	Chem. Dir., American Tar Products Co., Mellon Institute, Pittsburgh, Pa.
228	a	RIDSDALE, P. S.	Sec'y, American Forestry Association, Washington, D. C.
549	a	ROCCA, B. T.	Engr., Metals and Chemicals Extraction Corporation, 766 50th Avenue, Oakland, Cal. (1921).
183	c	RODD, THOS., JR.	Pres., The Rodd Co., Century Bldg., Pittsburgh, Pa.
14	c	(Charter) ROLLINS, H. M.	Supt., Gulfport Creosoting Co., Gulfport, Miss.
363	c	ROSS, PERCY A.	Supt. Treating Plant, El Paso and Southwestern Railroad, Alamogordo, N. M.
310	c	ROWLAND, J. W.	Gen. Tie Inspr., Baltimore and Ohio Railroad, Parkersburg, W. Va.
90	c	RUFLI, H. M.	Supt., Republic Creosoting Co., Indianapolis, Ind.
556	c	RUSSELL, WM. A.	Inspr. Green and Creosoted Material, R. W. Hunt Co., St. Helens, Oregon (1921).
465	c	RYAN, THOS. J.	Chief Tie and Timber Inspr., Chicago & Eastern Illinois Railroad, 307 S. Market St., Marion, Ill.
286	c	SACKETT, H. S.	Ass't Purch. Agt., Chicago, Milwaukee and St. Paul Railway, Chicago, Ill.
398	c	SCHILTHUIS, J. J.	United Indian Wood Exploitation Companies, Semarang, Java.
567	a	SCHLAFLY, J. J.	Vice Pres., Potosi Tie & Lumber Co., 410 Liberty Central Bldg., St. Louis, Mo. (1921).
496	c	SCHMAELZLE, K. J.	Sales Engr., Jennison-Wright Co., Toledo, Ohio.
206	c	SCHNATTERBECK, C. C.	Special Inspector in Charge Cross-ties, U. S. R. A., 904 Hurley-Wright Bldg., Washington, D. C.
513	a	SCHOELLKOPF, J. F., JR.	Pres., By-Products Steel Corporation, 706 Marine Trust Bldg., Buffalo, N. Y.
189	c	SCHOMBURG, T. A.	Pres., Continental Tie and Lumber Co., Denver, Colo.
85	c	SCHULZ, HARRY	Supt. Wood Preserving Plant, Salt Lake Route, Los Angeles, Cal.
432	c	SHINN, FORREST S.	Supervisor, Chicago, Burlington & Quincy Treating Plant, Galesburg, Ill.
51	c	SHIPLEY, GRANT B.	Pres., Pittsburgh Wood Preserving Co., Century Bldg., Pittsburgh, Pa.
378	c	SHIPLEY, JACK B.	Mech. Engr., Moore Shipbuilding Co., Oakland, Cal.
154	a	SHIPLEY, L. B.	Bernuth Lembcke Co., 171 Madison Ave., New York City.
89	c	SHUFORD, C. S.	Supt., Republic Creosoting Co., Mobile, Ala.
371	c	SILVESTER, EDMUND L.	Lumber and Creosote Inspr., 901 National Bank of Commerce Bldg., Norfolk, Va.

262 a SJODAHL, H. A. ----------Chief Chemist, Chatfield Mfg. Co., Cincinnati, Ohio.
15 c (Charter) SMITH, AMOS --Supt., Ayer and Lord Tie Co., Argenta, Ark.
291 c SMITH, FRANCIS P. -----Consulting Engr., Dow and Smith, 131 East 23rd St., New York.
45 c SMITH, LOWRY -----------Ass't Div. Engr., Eastern District, Northern Pacific Railroad, St. Paul, Minn.
34 c SMITH, P. A. -------------Ass't Mgr., Norfolk Creosoting Co., Norfolk, Va.
289 a SMITH, R. G. -------------Engr. & Chem., Standard Oil Co. of California, 200 Bush St., San Francisco, Cal.
216 c SMITH, V. C. --------------Cons. Engr., Government Railroads of India, c/o Parr's Bank, Haverstock Hill, London, N. W., England.
421 c SMITH, WM. D. -----------Cain-Hurley Lumber Co., 1153 People's Gas Bldg, Chicago, Ill.
135 c SMITH, W. J. -------------Tie and Timber Agent, Missouri, Kansas and Texas Railroad, St. Louis, Mo.
463 c SNOW, IRVING M. -------Ass't Supt., Pittsburgh Wood Preserving Co., Adelaide, Pa.
504 c SNYDER, C. H. -----------Cons. Civil Engr., 251 Kearny St., San Francisco, Cal.
558 c SPECHT, J. M. -----------Tie Agent, Southern Pacific Railway, 719 Yeon Bldg., Portland, Oregon (1921).
470 c SPENCER, WM. O. --------Supt., Wood Preserving Works, Southern Pacific Co., Los Angeles, Cal.
355 c SPORLEY, CHAS. M. ------National Pole Co., 2516 Doswell Ave., St. Paul, Minn.
427 c SPROAT, ROBT. -----------Chief Lbr. Inspr., Central Railroad of New Jersey, Port Reading Creosoting Plant, Port Reading, N. J.
248 c STAHL, K. F. -------------Consulting Chemist, General Chemical Co., 2318 Wharton St., Pittsburgh, Pa.
104 c STEINMAYER, O. C. ------Supr. Timber Pres., St. Louis-San Francisco, Springfield, Mo.
58 c STERLING, E. A. ---------Eastern Mgr., J. D. Lacey & Co., 42nd St. Bldg., New York City.
35 c STEWART, F. H. ----------Alamosa, Colo.
506 c STIBOLT, V. A. -----------Ass't Gen. Mgr., Natalbany Lumber Co., Hammond, La.
92 c STIMSON, EARL ----------Chief Engr. Maintenance, Baltimore and Ohio Railroad, Baltimore, Md.
375 c STOCKDALE, J. S. --------Purch. Agt., Pittsburgh Wood Preserving Co., Century Bldg., Pittsburgh, Pa.
285 c STOCKING, E. J. ----------Vice Pres., Central Creosoting Co., 111 West Washington St., Chicago, Ill.
429 c STOTTLEMYER, E. M. ----Gen. Foreman, Baltimore and Ohio Treating Plant, Green Spring, W. Va.
572 a STREHAN, GEO. E. -------Cons. Engr., Southern Pine Association, 112 West 42nd St., New York City (1921).
471 a STROTHER, GRAY O. ----Secy and Treas., Railway Tie Treating Co., 165 Broadway, New York.
312 c STULL, T. G. ---------------Chief Timber Inspr., Chicago, Indiana and Louisville Railway, Bloomington, Ind.
287 c SWAN, O. T. ----------------Sec'y, Northern Hemlock and Hardwood Manufacturers' Association, Oshkosh, Wis.
438 c SWARTZ, ALBERT -------Ass't Mgr. Rys., Toledo Railways and Light Co., Toledo, Ohio.

36 c TAYLOR, C. MARSHALL--Supt. Treating Plant, P. & R. and C. R. R. of N. J., Port Reading, N. J.
304 c TAYLOR, THOS. B. -------Ass't to Pres., American Creosoting Co., Louisville, Ky.
430 c TEBBY, C. E. ---------------T. J. Moss Tie Co., R. R. 1, Box 147, East St. Louis, Ill.
192 c TILLEY, C. M. -------------Timber Treating Inspr., Southern Railway, Slidell, La.
197 c TOWNSEND, T. G. -------50 East 58th Street, New York City.
16 a (Charter) TOWNSLEY, WM., JR., Grasselli Chemical Co., Cleveland, Ohio.
382 c TRACEY, JOHN H. ------Timber Inspr., Testing Division, City of Chicago, 3100 S. Sacramento Ave., Ill.
466 a TRUMAN, M. G. -----------Vice Pres., Carter Bloxonend Flooring Co., 332 S. Michigan Ave., Chicago, Ill.
139 c TRUMBULL, M. K. --------American Sugar Refining Co., 117 Wall St., New York City.

525 a UNDERWOOD, LAWRENCE H., Vice Pres., American Tar Products Co., 208 S. LaSalle St., Chicago, Ill.

17 c (Charter) VALENTINE, H. S., Supt., Eppinger and Russell Co., 165 Broadway, New York City.
439 c VANDERPOEL, WM. K. --Gen. Supt. Distribution, Public Service Electric Co., 80 Park Place, Newark, N. J.
65 c VAN METRE, RICKER ---Vice Pres., Joyce-Watkins Co., 332 S. Michigan Ave., Chicago, Ill.
523 c VESEY, ROBT. S. ----------Works Mgr., Wm. Christie & Co., Ltd., Christie's Wharf, London, S. E. 7, England.

141 c von LEER, H. J. ....Treating Inspr., Baltimore and Ohio Railroad, 601 South 8th St., Terre Haute, Ind.
46 c von SCHRENK, HERMANN Cons. Timber Engr., Tower Grove and Flad Avenues, St. Louis, Mo.
378 c VORUM, A. H. ....Inspection Engr., Western Electric Co., 195 Broadway, New York City.

326 c WADDELL, KENNETH M..Chemist, Jennison-Wright Co., Toledo, Ohio.
256 c WALLACE, H. ....Supt., Federal Creosoting Co., Rome, N. Y.
543 c WALSH, LIONEL O. P. ...Gen. Mgr., Dominion Tar & Chemical Co., 171 James Street, Montreal, Quebec (1921).
111 a WALSH, P. R. ....Pres., Walsh Tie Co., Security Bldg., Minneapolis, Minn.
468 c WALTER, FRED J. ....Nashville, Chattanooga and St. Louis Railroad, Nashville, Tenn.
420 c WASTJER, JOSEPH ......Sec'y, Indiana Tie Co., Evansville, Ind.
81 c WATERMAN, J. H. ....Supt. Timber Preservation, Chicago, Burlington and Quincy, Galesburg, Ill.
150 c WATKINS, W. T. ....Pres., Joyce-Watkins Co., 332 S. Michigan Ave., Chicago, Ill.
551 a WAUGH, FRANK A. ......Walter Waugh and Co., 4 Lloyd's Ave., London, England (1921).
387 c WEATHERLY, J. L. ......Sales Engr., Jennison Wright Co., 906 Crozer Bldg., Philadelphia, Pa.
134 c WEBER, J. M. ....Supt., Ohio Wood Preserving Co., Orrville, Ohio.
305 a WEGENER, RICHARD ...Pres., Standard Tar Products Co., Milwaukee, Wis.
79 h WEISS, HOWARD F. .....Cons. Engr., C. F. Burgess Laboratories, Madison, Wis.
516 c WEST, O. R. ....Ass't Div. Engr., Atchison, Topeka and Santa Fe Railway, San Francisco, Cal.
469 a WETMORE, WILLARD C..Residual Oils Corporation, 1318 People's Gas Bldg., Chicago, Ill.
565 a WHEELER, CHAS. L. ....Gen. Mgr., St. Helens Dock & Terminal Co., St. Helens, Oregon (1921).
484 c WHITE, FRANK G. ....Chief Engr., Board of State Harbor Commissioners, Ferry Bldg., San Francisco, Cal.
177 c WHITE, THOS. M. ....American Creosote Works, Louisville, Miss.
437 c WILKINSON, J. M. ....312 W. Chestnut St., Marion, Ill.
47 c WILLIAMS, J. C. ....Lumber Yard Foreman, Port Reading Creosoting Plant, Port Reading, N. J.
497 c WILLIAMS, J. W. ....Chief Engr., Northwestern Pacific Railroad, 64 Pine St., San Francisco, Cal.
138 c WILLIAMS, R. R. ....Pres. & Treas., Indiana Tie Co., Evansville, Ind.
399 c WILSON, ROGER ....Chemist, Republic Creosoting Co., Minneapolis, Minn.
478 c WILTSEE, W. P. ....Ass't Engr., Norfolk and Western Railway, Roanoke, Va.
426 c WOOD, GALEN ....Chemist, Philadelphia and Reading Railroad, Port Reading, N. J.
575 c WOOD, O. H. ....Ass't Purch. Agt., Great Northern Railroad, 324 King St., Seattle, Wash. (1921).
540 a WOOD, WM. PHILO ......Tar Products Corporation, 913 Turks Head Bldg., Providence, Rhode Island.
459 c WOODRUFF, H. W., JR....Gen. Mgr., Hattiesburg Creosoting Co., Hattiesburg, Miss.
485 c WYMAN, R. L. ....Inspector, Pacific Coast Forest Products, 437 Pittock Block, Portland, Oregon.

344 c ZELLER, W. C. ....Supt., American Creosoting Co. of New Jersey, Newark, N. J.

CLASSIFICATION OF MEMBERSHIP

Railroads

ATCHISON, TOPEKA & SANTA FE:
Belcher, R. S.
Brennan, T. S.
Cooper, S. D.
Curry, J. H.
Faulkner, E. O.
Jackson, W. E.
Keig, J. R.
Murray, D. L.
Pusinelli, J. A.
West, O. R.

BALTIMORE AND OHIO:
Alexander, E. E.
Angier, F. J.
Kimball, L. P.
Kittle, C. L.
Myerly, J. R.
Rabourn, M. M.
Rowland, J. W.
Stimson, Earl
Stottlemyer, E. M.
von Leer, H. J.

BUFFALO, ROCHESTER & PITTSBURGH:
Hoyt, H. B.

CANADIAN PACIFIC:
Dixon, J. H.

CENTRAL OF GEORGIA:
Harper, L. H.

CHICAGO, BURLINGTON & QUINCY:
Haggander, G. A.
Ingalls, E. E.
Shinn, F. S.
Waterman, J. H.

CHICAGO & EASTERN ILLINOIS:
Ryan, T. J.

CHICAGO GREAT WESTERN:
Graham, F. N.

CHICAGO, INDIANAPOLIS & LOUISVILLE:
Kent, A. S.
Stull, T. G.

CHICAGO, MILWAUKEE & ST. PAUL:
Pelz, E. N.
Pooler, F. S.
Sackett, H. S.

CHICAGO & NORTHWESTERN:
Bacon, W. L.
Davidson, Geo. M.

CHICAGO, ROCK ISLAND & PACIFIC:
Ford, C. F.
McCrory, Frank
Paul, H. A.

CLEVELAND, CINCINNATI, CHICAGO & ST. LOUIS:
Dixon, G. C.

DELAWARE, LACKAWANNA & WESTERN:
Gosline, C. E.

DETROIT & MACKINAC:
Amis, J. C.

EL PASO & SOUTHWESTERN:
Ross, P. A.

ERIE RAILROAD:
Bush, H. O.
Falconer, R. C.
Poux, R. R.

GOVERNMENT RAILROADS OF INDIA:
Smith, V. C.

GREAT NORTHERN:
Wood, O. H.

ILLINOIS CENTRAL:
Bowser, E. H.

LONDON & NORTHWESTERN (ENGLAND):
Bolsover, Guy

MISSOURI, KANSAS & TEXAS:
Elam, Wm.
Smith, W. J.

MISSOURI PACIFIC:
Graham, R. A.

NATIONAL RAILWAYS OF MEXICO:
Peimbert, Angel

NASHVILLE, CHATTANOOGA & ST. LOUIS:
Walter, F. J.

NEW YORK CENTRAL:
Green, C. W.

NORFOLK & WESTERN:
Bell, H. C.
Gibboney, J. H.
Wiltsee, W. P.

NORTHERN PACIFIC:
Gibson, Andrew
Smith, Lowry

NORTHWESTERN PACIFIC:
Williams, J. W.

OREGON-WASHINGTON RAILROAD & NAVIGATION COMPANY:
Pestel, A. C.

Railroads—(Continued)

PENNSYLVANIA:
- Black, J. M.
- Briggs, Z. M.
- Chilcoat, G. W.
- Condon, H. R.
- Foley, John
- Hopkins, H. W.
- Krell, F. C.
- McGinty, T. J.

PHILADELPHIA & READING:
- Sproat, R.
- Taylor, C. M.
- Williams, J. C.
- Wood, Galen

PITTSBURGH & LAKE ERIE:
- Clarke, Roy C.

ST. LOUIS & SAN FRANCISCO:
- Steinmayer, O. C.

SAN FRANCISCO-OAKLAND TERMINAL:
- Harris, Geo. H.

SAN PEDRO, LOS ANGELES & SALT LAKE:
- Schulz, Harry

SOUTHERN:
- Finke, W. F. H.
- Tilley, C. M.

SOUTHERN PACIFIC:
- Adams, Charles
- Anderson, Harvey A.
- France, R. L.
- Isaacs, John D.
- Jaekle, W. M.
- Kirkbride, W. H.
- Mattos, F. D.
- Specht, J. M.
- Spencer, W. O.

TEXAS & PACIFIC AND INTERNATIONAL AND GREAT NORTHERN:
- Kennedy, L. T.

UNION PACIFIC:
- Johnson, J. A.

WESTERN PACIFIC:
- Post, C. F.

WISCONSIN & NORTHERN:
- Hartley, H. C.

Street Railways

BOSTON ELEVATED RAILWAY COMPANY:
- Curtin, M. J.

TOLEDO RAILWAYS AND LIGHT COMPANY:
- Swartz, Albert

Commercial Treating Plants

AMERICAN CREOSOTING COMPANY:
- Austin, H. E.
- Crawford, C. G.
- Durham, J. H.
- Grady, W. H.
- Kuehn, A. L.
- Lawton, T. A.
- Taylor, T. B.

AMERICAN CREOSOTING COMPANY OF NEW JERSEY:
- Draper, E. G.
- Manion, Keron
- Zeller, W. C.

AMERICAN CREOSOTE WORKS:
- Labrot, S. W.
- White, T. M.

ATLANTIC CREOSOTING AND WOOD PRESERVING WORKS:
- Parrott, R. D.

AYER AND LORD TIE COMPANY:
- Armstrong, A. W.
- Lord, Russell
- Smith, A. M.

BURT, BOULTON AND HAYWOOD, LTD. (ENGLAND):
- Fergusson, Hubert

CANADA CREOSOTING COMPANY:
- Doan, W. E.
- Look, R. V.
- Moore, R. H

CENTRAL CREOSOTING COMPANY:
- Bade, J. H.
- Card, J. B.
- Hamilton, R. M.
- Stocking, E. J.

CHRISTIE, WM., AND COMPANY, LTD. (ENGLAND):
- Vesey, Robert S.

COLLSTROP, R., LTD. (DENMARK):
- Collstrop, A.

COLMAN CREOSOTING COMPANY:
- Colman, G. A.
- Colman, L. J.

Commercial Treating Plants—(Continued)

COMPRESSED WOOD PRESERVING COMPANY:
Frey, G. W.

CONTINENTAL TIE AND LUMBER COMPANY:
Schomberg, T. A.

CREOSOTED BLOCK PAVING COMPANY, LTD.:
Armstrong, Westropp
Lattimore, C. H.

CREOSOTED MATERIALS COMPANY, INC.:
Hamilton, F. P.
Manley, R. S.

DOMINION TAR AND CHEMICAL COMPANY:
Walsh, L. O. P.

EPPINGER AND RUSSELL COMPANY:
Chadwick, C. S.
Valentine, H. S.

ETABLISSEMENTS GAILLARD (FRANCE):
Boyer, Louis

FEDERAL CREOSOTING COMPANY:
Wallace, H.

GULFPORT CREOSOTING COMPANY:
Fant, A. E.
Rollins, H. M.

HATTIESBURG CREOSOTING COMPANY:
Woodruff, H. W., Jr.

INDIANA CREOSOTING COMPANY:
Burkhalter, D.

INDIANA TIE COMPANY:
Carman, C. E.
Cecil, W. A.
Merritt, H. T.
Wastjer, Jos.
Williams, R. R.

INDIANA ZINC CREOSOTING COMPANY:
Barber, Frank A.
McArdle, Frank

INTERNATIONAL CREOSOTING AND CONSTRUCTION COMPANY:
Allardyce, R. L.
Boehne, E. E.
Calder, R. J.
Latimer, J. D.

JENNISON-WRIGHT COMPANY:
Cherrington, F. W.
Dresser, G. L.
Ericson, L. T.
Jennison, H. G.
Schmaelzle, K. J.
Waddell, K. M.
Weatherly, J. L.

JOYCE-WATKINS COMPANY:
Joyce, A. R.
Van Metre, R.
Watkins, W. T.

KETTLE RIVER COMPANY:
Calvin, R. A.
Kneeland, R. E.
McElhinney, H. G.

MASSACHUSETTS LUMBER AND CREOSOTING CO.:
Bright, E. W.

MIDLAND CREOSOTING COMPANY:
Newton, H. M.

MONONGAHELA WOOD PRESERVING COMPANY:
Hoyt, W. E.

MOSS, T. J., TIE COMPANY:
Fristoe, J. W.
Penney, J. S.
Pershall, E. E.
Tebby, C. E.

NATIONAL LUMBER AND CREOSOTING COMPANY:
Harris, Page
Lawson, W. W.
Logan, J. T.
Rex, Geo. E.

NORFOLK CREOSOTING COMPANY:
Smith, P. A.

OHIO WOOD PRESERVING COMPANY:
Park, E. S.
Weber, J. M.

PACIFIC CREOSOTING COMPANY:
Book, J. E.
Chadbourne, B.
Horrocks, H. E.

PITTSBURGH WOOD PRESERVING COMPANY:
Peppler, R. A.
Shipley, Grant B.
Snow, I. M.
Stockdale, J. S.

RAILWAY TIE TREATING COMPANY:
Clements, C. M.
Loud, H. S.
Strother, G. O.

Commercial Treating Plants—(Continued)

REPUBLIC CREOSOTING COMPANY:
- Batson, C. D.
- Hess, L. E.
- Larkin, A. E.
- Powell, F. C.
- Rufli, H. M.
- Shuford, C. S.
- Wilson, Roger

ST. HELENS CREOSOTING COMPANY:
- Fairley, R. H.
- Garland, F. J.
- Meyer, E. H.
- Olson, John
- Osborne, C.

ST. PAUL AND TACOMA LUMBER COMPANY:
- Griggs, E. G.

SANTA FE TIE AND LUMBER PRESERVING CO.:
- Kistler, L. W.

SOUTHERN CREOSOTING COMPANY:
- Dunstan, J. H.
- Grant, J. D.
- Kelleher, W. J.

SOUTHERN WOOD PRESERVING COMPANY:
- Meredith, W. C.

VANCOUVER CREOSOTING COMPANY:
- Hermann, G. E.

WALSH TIE COMPANY:
- Furlong, L. A.
- Meyer, A.
- Walsh, P. R.

WATKINS CREOSOTING COMPANY:
- Helson, J. R.

WESTERN CEDAR POLE PRESERVERS:
- Leavitt, W. M.

WESTERN WOOD PRESERVING COMPANY:
- Lindsley, E. A.

Tie and Timber Companies

ALLEN, E. J.

AMERICAN LINE MATERIALS COMPANY:
- Carpenter, W. M.

AMERICAN TIE AND TIMBER COMPANY:
- Brown, S. K.

ANGUERA LUMBER AND TIE COMPANY:
- Clifton, W. H.

BAXTER, J. H., AND COMPANY:
- Baxter, A. M.

BLASSINGHAM, M. T., AND COMPANY:
- Blassingham, M T.

CAIN-HURLEY LUMBER COMPANY:
- Smith, W. D.

CHAPIN, E. T., CO.:
- Chapin, E. T.

CARTER BLOXONEND FLOORING COMPANY:
- Truman, M. G.

COOK, WM. P., AND COMPANY:
- Cook, Wm. P.

COONEY, ECKSTEIN AND COMPANY:
- Cooney, C. T.

CREO-FIR WOOD BLOCK PAVING COMPANY:
- Enright, F. M.

CROSS, AUSTIN AND IRELAND LUMBER CO.:
- Murchie, W. E.

FLORIDA LUMBER AND CRATE COMPANY:
- Bryan, Gordon

GILLIS AND COMPANY:
- Kehoe, H. B.

GOLTRA, W. F., TIE COMPANY:
- Goltra, W. F.

HINCKLEY, GEO. W., COMPANY:
- Hinckley, Geo. W.

HOBART LEE TIE COMPANY:
- Lee, Robert E.

KINZEL LUMBER COMPANY:
- Kinzel, L. K.

LONG-BELL LUMBER COMPANY:
- Ashby, H. N.
- Fritz, C. C.
- Frye, Ralph K.
- Martin, F. R.
- McKee, R. E.

McCORMICK, CHAS. R., CO.:
- Ball, W. C.
- McCormick, Chas. R.

Tie and Timber Companies—(Continued)

NASHVILLE TIE COMPANY:
Andrews, Howard

NATALBANY LUMBER COMPANY:
Stibolt, V. A.

NATIONAL POLE COMPANY:
Sporley, C. M.

NAUGLE POLE AND TIE COMPANY:
Morier, L. E.

PAGE AND HILL COMPANY, THE:
Burnes, J. D.
Hill, L. L.

POTOSI TIE AND LUMBER COMPANY:
Schlafly, J. J.

RODD COMPANY, THE:
Hicks, S. D.
Rodd, Thos., Jr.

ST. HELENS LUMBER COMPANY:
McCormick, H. F.

UNION CEDAR COMPANY:
Faylor, C. E.
Morris, F. M.

UNITED INDIAN WOOD EXPLOITATION COMPANIES:
Schilthuis, J. J.

VALENTINE-CLARK COMPANY:
Clark, E. L.

VON-PLATEN FOX COMPANY:
Fox, M. J.

WESTERN STATES LUMBER COMPANY:
McGrew, C. L.

WESTERN TIE AND TIMBER COMPANY:
Nixon, E. A.
Nixon, W. C.

WEYERHAEUSER FOREST PRODUCTS:
Hamilton, C. L.

WEYERHAEUSER TIMBER COMPANY:
Onstad, A. H.

Chemical Manufacturers, Importers, and Dealers, and Other Manufacturing Companies

ALLIS-CHALMERS MANUFACTURING COMPANY:
Grow, J. H.

AMERICAN TAR PRODUCTS COMPANY:
Davis, J. W.
Rhodes, E. O.
Underwood, L. H.

ARKANSAS ZINC COMPANY:
Fulks, E. B.

ASSOCIATED OIL COMPANY:
Jurs, L. D.

BARDEWYCK CO., R.:
Gutschow, Paul

BARRETT COMPANY, THE:
Barth, K. C.
Buehler, Walter
Church, S. R.
Mandenberg, E. C.

BERK, F. W., AND COMPANY, LTD. (ENGLAND):
Berk, P. F.

BERNUTH, LEMBCKE COMPANY, INC.:
Bernuth, Oscar
Fisher, Wm. A.
Kroemer, F. W.
Lembcke, G. A.
Shipley, L. B.

BLACKALL, ROBERT H.

C. A. WOOD PRESERVER COMPANY:
Gerhard, H. H.

CABOT, THE SAMUEL, COMPANY:
Cabot, Samuel

CHATFIELD MANUFACTURING COMPANY:
Sjodahl, H. A.

DU PONT CHEMICAL WORKS:
Kinsman, J. W.

FOREST PRODUCTS CHEMICAL COMPANY:
Clifford, W. E.

GENERAL CHEMICAL COMPANY:
Hawkes, A. W.

GRASSELLI CHEMICAL COMPANY:
Davis, H. E.
Drefahl, L. C.
Jordan, J. H.
Townsley, Wm.

GRAVER CORPORATION:
Gibson, W. C.

GREAT WESTERN ELECTRO CHEMICAL CO.:
Henderson, C. T.

Chemical Manufacturers, Importers and Dealers, and Other Manufacturing Companies—(Continued)

GREENLEE BROTHERS AND COMPANY:
Edwards, D. W.

INTERNATIONAL COAL PRODUCTS CORPORATION:
Bermingham, Edward

KERN COMMERCIAL COMPANY:
Greenebaum, Milton

KINNEY COMPANY, THE:
Kinney, N. B.

LEWIS, F. J., MANUFACTURING COMPANY:
Lewis, F. J.
Lewis, Wm. H.
Murphy, Wm. B.

LOCKETT, A. M., CO.:
Lockett, A. M.

METALS AND CHEMICALS EXTRACTION CORPORATION:
Moore, Granville
Rocca, B. T.

MINERAL POINT ZINC COMPANY:
Nitchie, C. C.

MONSANTO CHEMICAL WORKS:
Bradley, Mark
Queeny, John F.

NATIONAL ZINC COMPANY:
Leverett, W. H.

NEW JERSEY ZINC COMPANY:
Breyer, F. G.
Hendricks, W. H.

NORTHEASTERN COMPANY, THE:
Eastwick, C. H.

PARAFFINE COMPANIES:
Greig, Wm. R.

PIERCE FLUORSPAR COMPANY:
Pierce, H. B.

PROTEXOL CORPORATION:
Hartman, E. F.

REEVES COMPANY, THE:
Jahncke, W. F.

RESIDUAL OILS CORPORATION:
Wetmore, W. C.

SHELL COMPANY:
Cortes, C. E.

STANDARD OIL COMPANY OF CALIFORNIA:
Smith, R. G.

STANDARD TAR PRODUCTS COMPANY:
Wegener, Richard

TAR PRODUCTS CORPORATION:
Wood, W. P.

UNITED GAS IMPROVEMENT COMPANY:
Fulweiler, W. H.

WAUGH, WALTER, AND COMPANY:
Waugh, F. A.

ZOBEL, ERNST, COMPANY:
Gramm, C. W.

Chemists, Consulting Engineers, Inspectors, etc.

- Allerton, David
- Almon, W. D.
- Babcock, E. B.
- Baker, J. S.
- Becker, A. C.
- Berry, C. W.
- Brunnier, H. J.
- Collins, E. S.
- Crowell and Murray
  - Miller, D. B.
- DeCew, J. A.
- Dow and Smith
  - Dow, A. W.
  - Smith, F. P.
- Emerson Company, The
  - Emerson, Harrington
- Foersterling, Hans
- Goss and Rawson
  - Goss, O. P. M.
  - Rawson, R. H.
- Harrell, E. H., Co.
  - Harrell, E. H.
- Hendricks, V. K.
- Hunt, R. W., & Co.
  - Campbell, J. H.
  - Russell, Wm. A.
- Johnston, T. P.
- Judge, F. B.
- Kendrick, J. W.
- Lacey, J. D., & Co.
  - Sterling, E. A.
- Ray, John R.
- Silvester, E. L.
- Snyder, C. H.
- Stahl, K. F.
- Stewart, F. H.
- Townsend, T. G.
- von Schrenk and Kammerer
  - Kammerer, A. L.
  - von Schrenk, Hermann
- Weiss, H. F.
- Wilkinson, J. M.
- Wyman, R. L.

Governments

AMERICAN

U. S. FOREST SERVICE:
- Bateman, Ernest
- Deutsch, Margaret F.
- Heim, A. L.
- Hill, C. L.
- Hunt, Geo. M.

U. S. RAILROAD ADMINISTRATION:
- Schnatterbeck, C. C.

ARMY:
- Clarke, G. S.

CALIFORNIA BOARD OF STATE HARBOR COMMISSIONERS:
- White, F. G.

FOREIGN

FOREST RESEARCH INSTITUTE AND COLLEGE—INDIA:
- Pearson, R. S.

Educational Institutions

ARMOUR INSTITUTE OF TECHNOLOGY:
- Paul, C. E.

YALE UNIVERSITY:
- Record, S. J.

UNIVERSITY OF CALIFORNIA:
- Kofoid, C. A.

Associations

AMERICAN WOODS EXPORT ASSOCIATION:
- Brown, N. C.

NORTHERN HEMLOCK & HARDWOODS MANUFACTURERS' ASSOCIATION:
- Swan, O. T.

SOUTHERN PINE ASSOCIATION:
- Strehan, Geo. E.

WEST COAST LUMBERMEN'S ASSOCIATION:
- Hogue, C. J.

Firms Not Classified

AMERICAN SUGAR REFINING COMPANY:
- Trumbull, M. K.

AMERICAN TELEPHONE AND TELEGRAPH CO.:
- Eggleston, R. C.
- Hosford, R. F.

ASSOCIATED FACTORY MUTUAL FIRE INSURANCE COMPANIES:
- Hoxie, F. J.

BURD RING SALES CO. OF CANADA:
- Dixon, J. H.

BY-PRODUCTS STEEL CORPORATION:
- Golden, W. J.
- Kinkel, R. P.
- Schoellkopf, J. F.

CALIFORNIA AND HAWAIIAN SUGAR REFINING CO.:
- Brown, A. A.

DENVER METALS COMPANY:
- Moody, W. L.

FRICK, H. C., COKE COMPANY:
- Dawson, Thos. W.

HOGGSON BROTHERS:
- Fowler, J. W.

HUMPHREYS, C. L.

LUMBERMEN'S RAIL AND EQUIPMENT BUREAU:
- Moses, L. B.

MOORE SHIPBUILDING COMPANY:
- Shipley, Jack B.

POTTER-COYLE:
- Potter, H. R.

PUBLIC SERVICE ELECTRIC COMPANY:
- Vanderpoel, W. K.

ST. HELENS DOCK AND TERMINAL COMPANY:
- Wheeler, Chas. L.

WESTERN ELECTRIC COMPANY:
- Amadon, C. H.
- Vorum, A. H.

WESTERN SILO COMPANY:
- Martin, J. R.

WESTERN UNION TELEGRAPH CO.:
- Howe, P. J.

Municipalities

CHICAGO, ILL.:
- Tracey, J. H.

MINNEAPOLIS, MINN.:
- Davies, E. T.
- Dutton, E. R.

TORONTO, CANADA:
- Marriott, F. G.

Periodicals

"AMERICAN FORESTRY":
- Ridsdale, P. S.

"RAILWAY MAINTENANCE ENGINEER":
- Howson, E. T.

PROCEEDINGS

OF THE SEVENTEENTH ANNUAL MEETING OF THE AMERICAN WOOD-PRESERVERS' ASSOCIATION

OPENING SESSION

The Seventeenth Annual Meeting of the American Wood-Preservers' Association was held at Hotel St. Francis, San Francisco, Calif., January 25, 26, and 27, 1921, Mr. A. R. Joyce, President, presiding.

THE PRESIDENT: The Seventeenth Annual Meeting of the American Wood-Preservers' Association will come to order. We will be led in prayer by Reverend Doctor Rathbone. Let us all stand.

DR. RATHBONE: Oh, God, our Father, we are very glad to bow our heads this morning in Thy presence. Thou who art the author and the preserver of us all, Thou from whose hands dost come all the good gifts that we so richly enjoy. And, our Father, we are very glad this morning that we can come together here as those who are seeking one particular branch of Thy industry. We pray, our Father, Thy blessing upon us, not simply that our minds and hearts may be clear and steadfast, but that out of the vexations of life Thou wilt help us to think that all the things that Thou wouldst have us to do shall be the things that we shall do if it be pleasing in Thy sight. May our lives and our interests be blessed of Thee and wilt Thou lead us in the way everlasting; to Thee let us give praise forever and ever. Amen.

THE PRESIDENT: Ladies and Gentlemen, we are in the city of San Francisco. [*Applause.*] It is a very great pleasure to call on his honor, the Mayor of San Francisco, Mr. Rolph, to make us an address of welcome. [*Applause.*]

MAYOR JAMES ROLPH: Mr. President and Delegates to the Convention: I was very much cheered when you responded to the name of San Francisco in such a pleasing way this morning, which indicates you are happy to be in this city, and I want to thank the local committee for giving me the opportunity of welcoming you to this great city of the West.

This is your Seventeenth Annual Convention, and for the first time you have come to the Far West. Heretofore you have confined your activities to the East. St. Louis was, I understand, the farthest point West that you could see, but you have come out to the home of the pine and the redwood. You have come out to the place where the great trees are grown and the saw mills cut the trees. You in the East, to a great degree, preserve the products of the West, so it is only natural that after 17 years of discussing your own affairs in the East you come out West to see what we produce, the great domain that we live in, the great possibilities of this great country, and go back feeling better that you have come on out to get a whiff of the Pacific Ocean, and to know that out west of the Rocky Mountains there is a domain that you never dreamt of in the confines of the East.

California is a State 750 miles long and 250 miles wide, and you could put in the whole of the Atlantic bordering States into California and there would still be room for more. You could put the British Isles into California, and they would hardly be noticed. You could put the Empire of Japan into California, and it would not occupy much more territory than one big county in the State of California, and in San Francisco,—oh, my heart thrills when I speak of San Francisco. I am the proudest man in the whole United States to be Mayor of this great city—destroyed by fire three times. When I saw a number of the delegates this morning looking at the wonderfully carved ceiling of this magnificent room; that is just typical of what San Francisco is. San Francisco is just as fine as the carving on that ceiling, and that is the kind of a city we want you to see.

Fourteen years ago this hotel lay in ashes. For 5 miles on either side of this hotel there was nothing left of the old San Francisco that was, but the spirit of the West, the pluck, the energy, the determination to build, to be constructive. This is the spirit that the people of this city that was, made San Francisco the city that it is.

San Francisco has progressed in its municipal lines. You can travel around San Francisco for 5 cents. We have not raised the fares in San Francisco. It is only 5 cents to travel on the street cars.

We have our waterworks; we have rebuilt buildings; we have a group of buildings out at the City Hall which will make you think you are in the great city of Washington. We have things to see here that are well worth the coming. You can see where the Democratic Convention was held—the Convention, of course, was not very lucky for Cox and Roosevelt, they were not nominated here, but still we had the Democratic Convention. Now that the Democrats came out West, and we know the Republicans are coming, we are a great convention city. We are the world's exposition city. The nations of the world gathered here in 1915, and we welcomed people from all parts of the world to San Francisco.

Now that you have come let me say to you, do not spend all your time here talking about business. There will be business going on when you and I are gone. Have a little fun, "All work and no play makes Jack a dull boy."

I am in the lumber business and in the shipping business. I get very little time to attend to it, but still I know that a little recreation in a great city and in a great State, an opportunity to see some of the wonders of the world, to see Yosemite Valley, to see the mountain peaks, to see land below the sea level, to see the great valleys of the Sacramento and San Joaquin, to see all that we have here out in the West is your duty, the duty you owe to yourselves, the duty you owe to your associates, the duty you owe to your community while you are out here. It is your duty to get a grasp and a vision of what we have, to realize the possibilities of your business in the far Orient, see the ships traveling out of the Golden Gate, carrying out products to all parts of the world, and grasp that you are living in an age and in a country where the possibilities are nowhere greater than they are here on the Pacific Coast.

It is a pleasure to see you here; it is a pleasure to greet you, and, of course, I must confine myself to a word of welcome, but I would like to have the opportunity to stay and hear some of your discussions on business. I would like to hear some of you talk about the future of the country,—what is going to happen in the near future? It is on the minds of every man and woman. When are these panicky feelings and times going to pass away? When is confidence to be restored? What is the Republican administration going to do? How are the people of Europe going to finance themselves? When is the British pound and sterling exchange going to get back to normal? All these things are flitting through the minds of the American people today and these serious times require serious thoughts of serious men. However, in an address of welcome I must say we are glad to have you here and whatever San Francisco has got that you want we will be glad to give you. The country is dry out here. I do not know how it is in the place you come from, but I do not know of a place in San Francisco where you can get it. It is so dry here you cannot get a drop. Mr. Webb, on my right, is in charge of the Convention and Tourist League, and if you want a glass of "White Rock" or ginger ale or any of those intoxicating drinks we had 25 or 30 years ago as soft drinks, perhaps Mr. Webb can show you the real hospitality of the vine and the vineyard of golden California. So I bid you welcome to this great State, and hope you have a grand time while you are here. [*Prolonged applause.*]

THE PRESIDENT: We are going to call on our Past President, Mr. J. H. Waterman, to make the official response.

MR. J. H. WATERMAN: Mr. President, Ladies and Gentlemen, Mr. Mayor: It is a great pleasure to the Wood-Preservers' Association to gather in this great city of San Francisco, but it is a greater pleasure for them to have the Mayor put aside his work and take time enough to come here and welcome us to your city. If you had been with this bunch of men as I have for the past 10 days, you could appreciate more than you really know, when you turn the men over to the gentleman on your right to entertain them with "White Rock." There is only one "Waterman" in the bunch. [*Laughter.*] They chose him to respond to your address of welcome, because they knew before you stated that the city of San Francisco was dry.

We appreciate your great State more than you know. We have seen its mountains; we have seen its streams; we have enjoyed the fruit of your vines; we have enjoyed reading and hearing about San Francisco from the time we were little boys, and we know California is a great State, and the possibilities are that some of us will stay here after we have attended this Convention. But now let me tell you why this is a great State. You speak about the Eastern States, that there is plenty of room in California to take all the border States of the Atlantic and set them down in California and then they would be lost, there would be plenty more room, but I tell you what you should have stated: it is because the great men came out of the East and came and settled in this great State of California and they helped to build it up, and it was the rugged pioneers from the East that came here in '49 and followed on and on and on, that have given you the great advantages you have.

Now, you would like to know something about this convention. These are wood-preservers. I went down to a Bureau of Information in one of your cities, and I said to the lady,—I asked her a question, and I said, "I am a wood-preserver." "Well," she said, "what does that mean?" She seemed to think that we took the timber of this great land and put it up in bottles or cans and passed it around through the country. [*Laughter.*] Let me tell you what we do. We take the wood and your fir and your pine which will give 3 years', not to exceed 6 years' life untreated, we treat it chemically and what will it do? It will give from 12 to 20 years' life, depending upon where it is used and how well it is protected.

Is that not worth while? These men are conservers. They conserve the forests of our country, and the more they conserve the longer the forests will last, and we can hand them down to the generations that are yet unborn.

So, Mr. Mayor, if you want a man to fill any office in your city under you, why, just name the office and there are a half a dozen in this bunch who would stand up and fill it for you.

There is one thing I think you overlooked, and I am awfully sorry for it, and I think we are largely to blame. I think I am going to lay the blame all to our President. Because of these bright faces of the men that are in front of me, I think you overlooked our American beauties that we see sitting back of you. I know you will be glad to have them here, but I want to tell you they are the best in the land. We enjoy your poppies in California; we admire their complexions; we admire their appearance, their loveliness, but we have got just as beautiful east of the Rocky Mountains.

Now, Mr. Mayor, in behalf of the American Wood-Preservers' Association, I want to say to you that we all, men and women, appreciate your kind welcome, appreciate the time you have taken, and I assure you that if by accident or otherwise we wake up in jail, we will call you out of bed and we trust you will get us out. [*Applause.*]

THE PRESIDENT: The Minutes of the last meeting have been published in the PROCEEDINGS so that it is not necessary to read them at this time.

We will now have the report of the Secretary-Treasurer, Mr. Angier.

REPORT OF THE SECRETARY-TREASURER

To the Members of the American Wood-Preservers' Association:

Gentlemen: Your Secretary-Treasurer begs to submit herewith his Annual Report for the year 1920:

Cash on hand, December 31, 1919	$ 214.88
Liberty bonds on hand, December 31, 1919	500.00

Receipts

Admission fees	$ 970.00	
Membership dues	3150.72	
Advertising—Proceedings (1919)	44.00	
" " (1920)	1219.00	
" " (1921)	80.00	
Sales—PROCEEDINGS	439.48	
" HANDBOOK	11.35	
" "Decay of Ties in Storage"	227.00	
" Pamphlets—"Sodium Fluoride"	7.50	
" Pamphlets—"Long Wharf Bulletin"	70.00	
" WOOD-PRESERVING	5.00	
Donation by Entertainment Committee	275.50	
Interest—Bank deposits	28.36	
" —Liberty bonds	21.25	
		$6549.16
Total cash, bonds and receipts		$7264.04

Disbursements

PROCEEDINGS:		
Printing (1919)	$ 275.00	
" (1920*)	1893.51	
Advance papers	895.80	
Reporting	159.40	
Editing and soliciting advertisements	149.41	
Postage, expense and telegrams	90.82	
Storage and miscellaneous	22.00	
Compiling statistics (1920)	60.00	
" " (1921)	60.00	
Total	$3605.94	
GENERAL:		
Expense—Secretary-Treasurer's Office	$ 999.48	
Stationery, postage, express and telegrams	340.01	
Expense—1920 meeting	92.00	
" —1921 meeting	189.50	
Embossing certificates	32.90	
"Decay of Ties in Storage"	803.84	
"Long Wharf Bulletin"	70.00	
President's Bulletin	44.77	
Membership lists and certificates	72.90	
Membership—U. S. Chamber of Commerce	15.00	
" —National Conservation Association	3.00	
" —National Public Works Dept. Ass'n.	10.00	
Donation—Forest Products Laboratory—Decennial Celebration	25.00	
WOOD-PRESERVING—Bonus to Editor	74.18	
Address plates	5.78	
Total	$2778 36	
Total disbursements		$6384.30
Cash on hand, December 31, 1920	$ 379 74	
Liberty bonds on hand, December 31, 1920	500 00	
		879.74
		$ 7264.04

Note: *Bill for printing, amounting to $998.04, received too late for payment in 1920.

Service Bureau

RECEIPTS:		
Contributions		$2375.00
DISBURSEMENTS:		
Legal services	$ 25.00	
Recording charter	1 80	
Stationery	63.50	
		90.30
Cash on hand, December 31, 1920		$2284.70

Membership

Last annual report			305
Enrolled since last report		81	
Reinstated since last report		6	
		87	
Resigned	11		
Dropped	6		
Deceased	2		
		19	
Total net gain			68
Membership, December 31, 1920			373

Corporate	286	or	76.68%
Associate	77	or	20.64%
Probate	5	or	1.34%
Honorary	5	or	1.34%
	373	or	100.00%

Growth of Membership

Year	New Members	Withdrew	Added to Roll	Total
1904	20	--	20	20
1905	7	--	7	27
1906	9	7	2	29
1907	15	--	15	44
1908	5	4	1	45
1909	13	12	1	46
1910	29	8	21	67
1911	45	8	37	104
1912	59	6	53	157
1913	37	11	26	183
1914	92	10	82	265
1915	29	18	11	276
1916	41	18	23	299
1917	36	46	*10	289
1918	12	19	* 7	282
1919	48	25	23	305
1920	87	19	68	373
	584	211	373	
Average for 17 years	34	12	22	

*Deducted

It is very gratifying to know that 81 new members were enrolled, and 6 reinstated during the year. This is the largest number in any year in the history of the Association, with the single exception of 1914, when, under the splendid administration of Mr. Rex, 92 new members were added to our list. The increase in 1920 is due very largely to the efforts of our Pacific Coast members, who have given so much of their time and energy to the upbuilding of our Association.

While we rejoice in this increase in members, we bow our heads in sorrow over the death of two of our members, Mr. R. A. Griffin, who died July 14, 1920, and Mr. Chas. C. Higgins, November 3, 1920. Letters of condolence were written by your Secretary to the families of the deceased, and, as is our custom, resolutions will be passed by the Association.

During the year 11 members resigned and 6 dropped out, making a net increase of 68.

We regret to report that there are 18 members who are delinquent in the payment of their 1920 dues, and it is hoped that they will remit at an early date, together with their 1921 dues.

Classification of Members

		Members
40	Railroads	97
	U. S. Railroad Administration	4
2	Street railways	2
47	Commercial treating plants	103
25	Tie and lumber companies	37
43	Chemical and other manufacturing companies	63
1	National government	7
4	Educational institutions	4
4	Municipalities	5
2	Periodicals	2
4	Associations	5
11	Firms not classified	12
	Consulting engineers, chemists, etc	31
	United States Army	1
		373

Geographical Distribution

State	1914	1915	1916	1917	1918	1919	1920
Alabama	4	3	3	3	3	2	2
Arkansas	5	4	3	4	3	3	4
California	5	6	6	6	5	11	28
Colorado	3	2	2	2	2	1	2
Connecticut	1	1	1	1	1	1	1
Delaware	--	--	--	--	--	1	1
District of Columbia	4	4	4	5	5	7	4
Florida	4	3	3	3	3	3	2
Georgia	2	5	5	3	2	1	2
Illinois	35	41	41	44	46	51	50
Indiana	6	8	10	9	6	16	14
Iowa	2	1	1	1	1	1	1
Kansas	4	4	4	5	6	3	1
Kentucky	7	8	8	7	7	7	7
Louisiana	10	12	13	12	9	13	17
Maryland	5	5	7	8	6	2	3
Massachusetts	2	3	3	5	4	4	5
Michigan	2	3	5	7	7	3	1
Minnesota	9	10	12	11	9	10	13
Mississippi	3	3	3	3	2	2	4
Missouri	12	12	15	12	14	17	24
New Jersey	7	6	7	7	6	10	11
New Mexico	3	3	3	2	2	2	4
New York	21	24	28	29	33	35	47
Ohio	11	12	12	12	15	19	18
Oregon	7	5	5	6	5	5	8
Pennsylvania	14	12	12	16	18	17	25
Rhode Island	--	--	--	--	--	--	1
Tennessee	3	2	2	2	3	3	4
Texas	17	13	14	13	13	13	11
Virginia	3	3	4	5	4	3	7
Washington	16	17	18	14	11	6	11
West Virginia	--	--	--	2	2	4	7
Wisconsin	8	9	12	10	10	9	11
Wyoming	3	3	2	2	1	1	1
Address Unknown	--	--	--	--	--	--	2
	240	251	272	271	264	286	354
Country							
Austria	1	1	1	--	--	--	--
Canada	14	13	14	13	11	11	9
Denmark	--	--	--	--	1	1	1
England	4	4	5	5	4	3	5
France	--	--	--	--	--	1	1
Germany	6	6	6	--	--	--	--
India	1	1	1	1	1	1	1
Java	--	--	--	--	1	1	1
Mexico	--	--	--	--	--	1	1
Russia	--	--	--	1	--	--	--
	265	276	299	291	282	305	373

In the Geographical Distribution, Illinois is still in the lead with 50 members, while New York is a close second with 47 members. California ranks third with 28 members, having increased 17 during the year.

In my report for last year I suggested that we make 1920 the banner year for our Association, and we came pretty nearly doing it. I want to repeat this, and ask the co-operation of all of our members in making 1921 the banner year. Let's all pull together, each one making an extraordinary effort to get at least one new member. If we can do this, our next report will show a membership of over 700.

Respectfully submitted,

(Signed) F. J. ANGIER, Secretary-Treasurer.

ATTENDANCE AT THE SEVENTEENTH ANNUAL MEETING

The registration showed the following attendance at the meeting:

Members

Adams, Chas.
Alexander, E. E.
Allardyce, R. L.
Allerton, David
Anderson, H. A.
Andrews, Howard
Angier, F. J.
Barth, Kurt C.
Baxter, A. M.
Belcher, R. S.
Brennan, T. S.
Brown, A. A.
Brunnier, H. J.
Buehler, Walter
Card, J. B.
Cooper, S. D.
Cortes, Carlos E.
Crawford, Carl G.
Davis, H. E.
Drefahl, E. C.
Dutton, Ellis R.
Edwards, D. W.
Fairley, R. H.
Faulkner, E. O.
Foley, John
Ford, C. F.
France, R. L.
Frey, Geo. W.
Gibson, Andrew
Gosline, C. E.
Graham, F. N.
Grow, J. H.
Hicks, S. D.
Hill, C. L.
Hill, L. L.
Horrocks, H. E.
Hosford, Roger F.
Howson, E. T.
Hunt, Geo. M.
Jaekle, W. M.
Johnson, J. A.
Joyce, A. R.
Jurs, Louis D.
Kammerer, Alfred L.
Keig, J. R.
Kirkbride, W. H.
Kofoid, Dr. Chas. A.
Larkin, A. E.
Leavitt, W. M.
Lembcke, G. A.
Lindsley, E. A.
Mattos, Frank D.
McCormick, Chas. R.
Nixon, Warren Case
Osborne, Clyde W.
Pelz, E. N.
Post, C. F.
Powell, F. C.
Pusinelli, John A.
Smith, W. J.
Snyder, C. H.
Spencer, W. O.
Sporley, C. M.
Sproat, Robt.
Steinmayer, O. C.
Stocking, E. J.
Taylor, C. Marshall
von Schrenk, Hermann
Waterman, J. H.
West, O. R.
White, Frank G.
Williams, J. W.
Wilson, R. O.
Wyman, R. L.

Non-Members

Amadon, C. H.
Ball, Edgar E.
Ball, W. C.
Best, W. E.
Bowers, N. A.
Burckhalter, F. L.
Clausen, E. C.
Cochran, H. M.
Colclaugh, Ernest
Cornwall, Geo. M.
DeMuth, R. E.
Dinsmore, Frank S.
Duval, W. M., Jr.
Elder, S. M.
Fritszchle, J. C.
Fritz, Emanuel
Greenleaf, E. N.
Gunn, Ray E.
Hall, James L.
Hickey, H. B.
Hickey, Henry B., Jr.
Hiscox, R. C.
Johnson, John H.
Johnson, Robert H.
Judson, C. H.
Lorenz, G. W.
Matthias, J., Jr.
McIlravy, W. N.
McClintock, Dr. J. A.
McGough, N. W.
McGuin, J. T.
McNeil, J. E.
Melton, J. K.
Meyer, Leo W.
Morrison, W. W.
Moss, T. J.
Muhs, Fred R.
Ogle, E. G.
Oglevee, O. S.
Oliver, Walter H.
Onstad, A. H.
Owens, James M.
Paul, W. A.
Rear, G. W.
Ross, P. A.
Russell, A. A. M.
Schlafly, J. J.
Schussler, M. H.
Scott, W. A.
Searight, F. Harvey
Smith, H. L.
Smith, Reuben W.
Squire, Harry E.
Tillotson, M. R.
Webb, R. L.
Wheeler, Chas. L.
Witherell, R. J.
Wismer, Einar

AMERICAN WOOD-PRESERVERS ASSOCIATION JAN. 25TH TO 27TH
THE NATIONAL ASSN. OF RAILROAD TIE PRODUCERS " 27TH . 29TH
HOTEL ST. FRANCIS SAN FRANCISCO CALIF. 1921.
KELLY TIRES
2372 PINE ST

AMERICAN WOOD-PRESERVERS' ASSOCIATION AND NATIONAL ASSOCIATION OF RAILROAD TIE PRODUCERS IN JOINT CONVENTION, SAN FRANCISCO, CAL.

MEMBERS OF AMERICAN WOOD-PRESERVERS' ASSOCIATION AT SAN FRANCISCO.

THE PRESIDENT: We will refer the Report of the Secretary-Treasurer to an Auditing Committee, composed of Geo. M. Hunt (Chairman), Chas. Adams, S. D. Hicks, and C. M. Sporley.

Before calling for the Report of the Entertainment Committee, we will appoint a special Resolutions Committee to prepare an appropriate resolution covering the death of E. M. Blake. This Committee will consist of C. L. Hill (Chairman), S. D. Cooper, and John Foley.

We will now have the Report of the Committee on Entertainment, Mr. France.

Mr. France then announced the entertainment the local Committee had provided for those in attendance at the Convention.

THE PRESIDENT: We will appoint the following Election Tellers: (they will report to the Secretary-Treasurer who will turn over to them at the proper time the ballots, and they in turn will report back to the Convention): R. L. Wyman (Chairman), L. C. Drefahl, J. H. Grow, G. A. Lembcke, and C. T. Henderson.

We will also appoint a Committee on Resolutions. Those of you who have things in mind that should be covered by resolutions will confer a favor upon this Committee by getting in touch with them. The Committee is as follows: C. F. Ford (Chairman), F. D. Mattos, G. W. Frey, A. M. Baxter, E. N. Pelz, and O. C. Steinmayer.

PRESIDENT'S ADDRESS

In the evolution of man there was a time when, obeying a blind instinct, he hunted man; a time when the man who lived on one side of the mountain or on one side of a swamp would kill the fellow that lived on the other side of the mountain or on the other side of the swamp, not because he hated him, but really because he did not understand him. There was a time in the development of the wood-preserving industry when the man who used fish oil or linseed or sulphate of lime or arsenic or verdigris, or those many things that have been tried in the preservation of wood, would do anything he could to kill the business of the man who was using zinc chloride or sodium fluoride or creosote oil or some other wood-preservative.

Today we have learned that good treatments, using standard preservatives and standard methods, all give good results. We have learned that the man with the wood-preserving plant living around the corner out of sight is not our enemy, a fellow to be killed on sight; he is our friend. We have learned that when he does good work it helps us, and we have also learned that when we do good work it helps him.

Gentlemen, we are standing today on the eve of a tremendous expansion in our industry. There are inquiries for wood-preserving equipment and wood-preserving materials coming in from all the countries of the earth.

From this country the lumber industry in particular is making many inquiries as to the treatment of kinds of lumber that have never been treated before.

Men, let us remember as we go into this period of expansion that good practices have obtained the results that today we are proud of, and that those practices must be continued. Let us uphold the standards of our industry. [*Applause.*]

THE PRESIDENT: We will now have the Report of the Committee on Publications, Mr. Howson, Chairman.

MR. E. T. HOWSON: Mr. President and Members of the Association: The work of your Committee on Publications during the past year has been largely concentrated on two projects. One of these is the regular work of getting out the PROCEEDINGS, copies of which have been mailed to all members of the Association,—you are best able to judge the efficiency of the work of the Committee in that respect. The second project involved undertaking by your Committee, on instructions of the Executive Committee, of the publishing in separate form of the excellent paper on decay of ties presented at the last convention by Mr. C. J. Humphrey of the Forest Products Laboratory. This paper was considered of such value to the man in the field that the Executive Committee instructed the Publications Committee to arrange for the publication of this paper in a form which could be carried in the field. Therefore, it was prepared in a more durable, flexible binding, and has been printed. I think you have all been advised that the book is now available in separate form, and the report of the Secretary-Treasurer indicates that a considerable number have been sold since that time. As you all know that report includes a number of colored plates, and I think it is the most ambitious work of a publication nature that has yet been undertaken by this Association.

A third departure or innovation undertaken by the Committee this year at the suggestion of, and with the co-operation of, your officers and President, has been the sending out of two or three news-letters. Shortly after the last convention a news-letter was sent to the members, designed to inform them of the activities of the Association. That has been followed by one or two other news-letters which have gone to all members of the Association.

The Publications Committee has had splendid co-operation from the members of the Association in its work, and desires to express its appreciation of that co-operation. [*Applause.*]

THE PRESIDENT: A motion to accept the Report of this Committee will be in order.

MR. E. J. STOCKING: I move its acceptance.

MR. L. C. DREFAHL: I second the motion.

THE PRESIDENT: All in favor of this motion will respond by saying "aye"; contrary "no"; it is carried and so ordered.

Mr. Taylor, will you please take the Chair?

(Mr. C. M. Taylor assumes the Chair.)

THE CHAIRMAN: The next will be a Report of Committee No. 3 on Promotion and Education, of which Mr. Joyce is Chairman.

REPORT OF COMMITTEE NO 3—PROMOTION AND EDUCATION

To the Members of the American Wood-Preservers' Association:

A meeting of your Committee was held in Chicago in April, at which time the Service Bureau policy shown in Exhibit "A" was decided upon.

The Chairman of the Committee was instructed to get legal advice on two points:

(1) The right of the Association to collect funds and establish a Service Bureau.

(2) A form of contract to be entered into between the contributing companies and the Association.

The Chairman took council, and is pleased to advise, that the articles of incorporation of the American Wood-Preservers' Association have been duly recorded as required by the Illinois laws, and our Association is, therefore, legally organized.

We are further advised that the object clause of our articles of incorporation is broad enough to permit us to carry out the Service Bureau policy and the establishment and maintenance of a central office in charge of a salaried executive.

The expenditure of funds, irrespective of amount, is permissible, provided pecuniary gain to the individual members of the Association does not directly follow therefrom.

Our attention is respectively called to the recent action of the Federal Government against the Hardwood Manufacturers' Association and the Linseed Oil Association, in both of which cases the Government contends that these associations are illegally controlling prices.

There is nothing in our articles of incorporation or in our Service Bureau Policy which even intimates that our Association is in such a position and our attention is directed to the above action of the Federal Government in order that we may not knowingly infringe the Federal trade and trust laws.

Your Committee decided that the Service Bureau be financed for 3 years on a minimum basis of not less than $20,000.00 per year, and that definite binding obligations covering this period be secured before putting the Service Bureau into operation.

The obligation form is shown in Exhibit "B."

In December, 1920, the forms shown in Exhibit "A" and Exhibit "B" were arranged for and distributed to the Committee. As a result of this action the firms shown on Exhibit "C" have entered into the Service Bureau agreement to the extent of the sums shown opposite their names.

A. R. JOYCE, (*Chairman*),
E. M. BLAKE,
R. J. CALDER,
R. A. CALVIN,
J. B. CARD,
H. G. JENNISON,
G. A. LEMBCKE,
R. S. MANLEY,
W. A. NIXON,
E. J. STOCKING.

Exhibit "A"

To promote the use of wood which has been prepared to resist decay, and thereby conserve the forest resources of the nation, the American Wood-Preservers' Association proposes to establish and maintain a headquarters which shall be a repository for all information regarding the practice of and the results from the art of wood preservation and which shall utilize this information in all efficient ways to disseminate this knowledge and to develop the understanding of the public as to the economic status of the wood-preserving industry.

In furtherance of the program outlined above, the American Wood-Preservers' Association proposes to engage the services of a man who will have charge of the headquarters referred to and direct all work connected with the proposed campaign of education, promotion and publicity.

As Manager of the Service Bureau of the American Wood-Preservers' Association, this officer

1—Will answer inquiries regarding the treatment of wood and the use of treated wood;

2—Will acquaint users of wood with facts and figures to show where treated wood can be used where substitutes are being given consideration;

3—Will acquaint preservers of wood with facts and figures which show where treated material has proved either satisfactory or unsatisfactory;

4—Will attend and address meetings where those present can be told about wood preservation to the advantage of the industry;

5—Will accumulate service records and samples and develop a library and a museum which will demonstrate the effectiveness of wood preservation.

6—Will procure the publication of facts and figures which will acquaint the users of wood with the advantages of preservative treatment;

7—Will acquaint the wood-preserving industry with new opportunities for the sale of wood which might be given preservative treatment;

8—Will endeavor to procure from both the producer and the user of treated wood strict compliance with the standard practices of the American Wood-Preservers' Association.

9—Will disseminate information by means of a periodical or otherwise which will acquaint the users of wood and the preservers of it with the developments and possibilities in the wood preserving industry.

Exhibit "B"

------------------------------------, 192---

The undersigned, ----------------------------------, in consideration of other similar subscriptions, hereby agrees with such other subscribers and with the AMERICAN WOOD-PRESERVERS' ASSOCIATION, to contribute the sum of --Dollars, toward the proposed fund to finance a campaign of education covering the uses of preserved wood, said sum to be payable in equal installments to the Treasurer of said Association, as follows:

$------------------------------, 1920
$------------On or before July 1, 1921
$------------On or before Jan. 1, 1922
$------------On or before July 1, 1922
$------------On or before Jan. 1, 1923
$------------On or before July 1, 1923

Interest to be payable on all installments at the rate of six percent per annum after maturity. It is further agreed that all payments after the first are conditioned upon the Association securing subscriptions aggregating the sum of $60,000.00.

Make Checks payable to
F. J. ANGIER, Secy.-Treas.,
Mt. Royal Station,
BALTIMORE, MD.

------------------------------ (Seal)
By ----------------------------------
(Official Title)

Exhibit "C"

Name	Total Subscription	Amount Paid
American Creosoting Co.	$ 9000.00	--------
American Creo. Co. of N. J.	1500.00	$ 250.00
Ayer & Lord Tie Co.	1500.00	--------
The Chatfield Mfg. Co.	600.00	--------
Colman Creosoting Works	1500.00	--------
Compressed Wood-Preserving Co.	750.00	125.00
Creosoted Materials Co.	1500.00	250.00
Indiana Zinc Creosoting Co.	1500.00	250.00
International Creosoting & Construction Co.	1000.00	1000.00
F. J. Lewis Mfg. Co.	1000.00	--------
National Pole Co.	600.00	200.00
Southern Creosoting Co.	1500.00	500.00
Southern Wood-Preserving Co.	900.00	150.00
Watkins Creosoting Co.	1500.00	250.00
Western Tie & Timber Co.	500.00	100.00
	$24,850.00	$3075.00

THE CHAIRMAN: Gentlemen, you have heard the Report of the Committee on Promotion and Education. I would like just at this time to express the thought that I know is in the minds of all of you, that our President this year has been able to put across this thought that has been in the minds of a great many of us for some years past. As he has already told you the wood-preserving industry is on the threshold of a great era of expansion, and in this manner we shall be able to take care of the proper kind of promotion as should go along with that expansion. I would be glad to have discussion on this report.

MR. A. E. LARKIN: I would like to make a motion that the report of this Committee on Promotion and Education be accepted and the Committee discharged with the thanks of the Association.

MR. F. D. MATTOS: I second the motion.

THE CHAIRMAN: It has been moved and seconded that this report be accepted and the Committee be discharged with the thanks of the Association. Are there any remarks? All in favor of that motion please say "aye"; opposed, "no"; it is so ordered.

MR. A. R. JOYCE: Mr. Chairman, I would like to make the following motion: I move that the following Service Bureau Board be established: C. G. Crawford (Chairman), Walter Buehler, L. J. Colman, L. C. Drefahl, R. S. Manley, G. B. Shipley, and E. J. Stocking with duties as follows:

(1) To complete the campaign to finance the Service Bureau.

(2) To engage a competent executive and establish a central office.

(3) To direct the work of the Service Bureau for the 3-year guaranty period.

(4) To administer the finances of the Service Bureau.

(5) To report to the Association through its Executive Committee.

MR. J. H. WATERMAN: I second that motion.

THE CHAIRMAN: It has been moved and seconded that the motion just read by Mr. Joyce, our President, in reference to the Service Bureau be adopted. Are there any remarks connected with this motion? Please get this clear in mind now—this is the Service Bureau to have charge of all the work in connection with promotion and education. It is composed of men connected with the commercial phase of our industry, covering both the men that are actively engaged in treating work and those interested in the preservative materials. I will read the Committee again. (Mr. Taylor reads the names of those appointed on the Committee again.) I think we can feel safe in leaving our promotion work in the hands of this Committee. All in favor of this motion as put by Mr. Joyce please say "aye"; opposed like sign; it is so ordered.

(Mr. Joyce resumes the Chair.)

AFTERNOON SESSION

Tuesday, January 25, 1921.

THE PRESIDENT: The meeting will come to order. We will have the Report of Committee No. 4 on Preservatives. Will the Committee please come forward?

(Mr. Taylor assumes the Chair.)

REPORT OF COMMITTEE NO. 4—PRESERVATIVES.

To the Members of the American Wood-Preservers' Association:

Your Committee on Preservatives submits herewith its report to the seventeenth annual convention.

The instructions of the Executive Committee to this Committee were as follows:

(I) Investigate suitability of water-gas tar and products of water-gas tar for use in preservative treatment of wood.

(II) Develop standard methods for handling zinc chloride at wood-preserving plants, including the calculations involved.

(III) Determine the effect of various quantities of zinc chloride on the strength of zinc-treated wood.

(IV) Complete investigations of the sampling of tank cars.

Two meetings of the whole Committee were held at Cleveland, Ohio; the first on June 8, 1920, at which 7 members were present, and the second on October 4 at which 8 members were present.

On account of its increasing economic importance, the Committee at its first meeting decided to add the subject of "vertical retort tar" (V) to the list of subjects assigned by the Executive Committee.

The detailed work of the Committee was done by means of small sub-committees, the chairman having appointed a sub-committee for each of the subjects included in the instructions, as follows:

Water-Gas Tar: W. H. Fulweiler, *Chairman.*
K. M. Waddell.
Zinc Chloride: Galen Wood, *Chairman.*
Ernest Bateman.
F. G. Breyer.
L. S. Drefahl.
Strength of Zinc-Treated Wood: Ernest Bateman.
Car Sampling: S. R. Church.

I.—Suitability of Water-Gas Tar and Products for Preservative Treatment.

A comprehensive report on this subject was presented at the second general meeting by the sub-committee chairman. After considerable discussion it was agreed that certain changes and omissions were to be made. The report was then to be re-submitted for consideration by the Committee. The revised report did not reach the chairman until December 11, 1920, having been delayed in the hope of getting certain data on oils extracted from old service ties. The late arrival of the report prevented its reconsideration by the Committee. As the Committee has taken no action on the report in its final form it will be presented as submitted by the chairman of the sub-committee, Mr. W. H. Fulweiler, in a separate paper.

II.—Zinc Chloride.

In its consideration of this subject the Committee has placed a broad interpretation on the original instructions of the Executive Committee. The subject has been expanded to include, in addition to the handling of zinc chloride at the plants, a general discussion of some of the physical and chemical properties of zinc chloride, methods of analysis, specific gravity tables, visual penetration test, etc.

The subject is presented in the order of the following outline:

- (1) Basic zinc chloride.
    - (a) Chemical composition and behavior.
    - (b) Solubility of zinc oxide in concentrated zinc chloride solution.
    - (c) Recovery of sludge.
- (2) Shrinkage of zinc chloride solutions on dilution.
- (3) Impurities in commercial 50% zinc chloride and high gravities.
- (4) Methods of analysis.
    - (a) Revision of standard volumetric ferrocyanide method of analysis.
    - (b) Tentative gravimetric method.
    - (c) Tentative volumetric method for quick, routine analysis.
- (5) Sampling zinc chloride.
    - (a) Fused.
    - (b) Liquid or 50%.
- (6) Specific gravity table.
- (7) Working table for plant use.
    - (a) Preliminary data.
    - (b) Working table in gallons and pounds.
- (8) Methods of figuring zinc chloride dilutions and concentrations.
    - (a) Discussion of method.
    - (b) Cases and concrete examples.
- (9) Method of figuring volumetric absorption.
- (10) Visual method of determining zinc chloride penetration.

(1) BASIC ZINC CHLORIDE.—(a) Chemical composition.

It is a familiar fact to the wood-preserver that the zinc chloride solutions received by him in drums or tank cars, or the strong solution (usually 50% or 50°Bé.) made by dissolving fused zinc chloride, when diluted with water to the gravities used for timber injection, deposit a white, slimy, flocculent precipitate known as "sludge", "oxychloride", or "basic". This sludge accumulates in the tanks and cylinders and is eventually thrown away.

The white flocculent material which separates when fused or granulated zinc chloride is dissolved in water and diluted to approximate infinity, has a composition after washing and drying at 212°F. as follows:

Sample No.	*Zinc* Per Cent	*Chlorine* Per Cent
1	59.90	11.61
2	61.30	11.87
3	60.79	11.14

The hypothetical composition of this material is approximately $2Zn(O\ H)_2ZnO\ HCl$. Theoretically, such a compound would contain 61.30% zinc and 11.20% chlorine.

It is a familiar fact that this precipitate can be dissolved in hydrochloric acid, and that the addition of hydrochloric acid can be so regulated as to form a neutral solution.

A concentrated solution of zinc chloride can be prepared in which the zinc and chlorine are stoichrometrically equivalent. If one dilutes a portion of such a solution to about 1% strength it will be noticed that the resulting solution is neutral to methyl orange. On the other hand, the original solution is strongly acid to methyl orange.

If pure zinc oxide is added to the above concentrated solution of zinc chloride it will be found that up to a certain point the oxide is soluble in the solution. How much is soluble seems to be dependent on the temperature and concentration of the solution. But even if the solution is saturated with oxide, it reacts acid to methyl orange indicator as before. When dilution to 1% or 2% takes place, substantially the entire zinc oxide added is precipitated not as oxide, but as a compound of zinc, oxygen and chlorine of indefinite formula.

The alkalinity of this precipitated "zinc oxychloride" enables us to determine the amount of the same by titration of a weighed sample with standard acid, using methyl orange as indicator. For convenience the result can be expressed as zinc oxide, ZnO, but if we desire the value of zinc oxychloride, it is necessary to multiply the result by the factor 1.45, which is the empirical relationship between acidimetrically equivalent weights of oxychloride and zinc oxide.

(b) Solubility of zinc oxide in zinc chloride.

It is interesting and useful to know how much zinc oxide is soluble in zinc chloride solutions of various concentrations and at various temperatures, so that the wood-preserver can forecast how much sludge will be formed under his conditions of dilution and temperature. It is to this end that the following table has been prepared:

ZINC OXIDE SOLUBLE IN ZINC CHLORIDE SOLUTIONS.

Specific Gravity	80°C	60°C	40°C	20°C
	Per Cent	*Per Cent*	*Per Cent*	*Per Cent*
1.7403	2.780	2.7000	2.140	1.660
1.6456	2.110	1.9100	1.790	1.720
1.5641	1.940	1.7200	1.540	1.390
1.4946	1.990	1.5100	1.210	1.070
1.3993	1.270	1.0600	.890	.700
1.3172	.900	.7300	.560	.440
1.2862	.790	.6100	.480	.370
1.2270	.520	.4700	.330	.240
1.1664	.380	.2700	.190	.140
1.1244	.270	.1700	.097	.058
1.0711	.099	.0600	.....	.....
1.0525	.061	.0200	.....	.....
1.0334	.040	.0013	.....	.....
1.0200	.021	......	.....	.....

(c) Recovery of sludge:

In the forepart of this report the composition of basic zinc chloride on dry basis is given, namely about 61% zinc and 11% chlorine. Fused zinc chloride contains from 1½% to 2% basic material. This is completely thrown out on dilution to a 4% solution. In a carload of 60,000 lbs. of fused zinc chloride about 900 lbs. to 1,000 lbs. will be thrown out of solution. This insoluble zinc can be made available by the direct addition of commercial muriatic acid, if suitable tank equipment is at hand, namely, wooden tanks equipped with paddles for stirring. Competent chemical supervision is also essential so that the sludge neutralization can be accurately controlled. The question is simply one of economics. The superintendent of a plant can calculate whether or not it will pay him to salvage the basic material by direct solution in acid as indicated above; that is, he will know from the amount of material he handles whether or not it will pay him to put up and maintain the equipment and chemical control necessary to recover this sludge.

It is considered safe practice when neutralizing sludge with muriatic acid to add just enough acid to leave a little basic material undissolved as an indicator of basicity. In this way the danger of injury to the plant equipment by corrosion due to an excess of acid will be avoided. The operator must be sure, however, that the supposed undissolved basic material is oxychloride and not some other white precipitate, as barium sulphate, etc.

(2) SHRINKAGE OF ZINC CHLORIDE ON DILUTION.—It is well known that when a concentrated zinc chloride solution is diluted with water to working strengths, a shrinkage in volume takes place. To determine the exact amount of this decrease in volume the following investigation

was made using a chemically pure neutral zinc chloride solution having an actual zinc chloride content of 51.41%.

> A 1000 c.c. flask was calibrated against a 100 c.c. calibrated burette, and these used in measuring the quantities of water and zinc chloride.
>
> 952 c.c. of water at 70°F. were run into the flask and 48 c.c. of zinc chloride at the same temperature, the mixture shaken and cooled to 70°F., then enough water was added from the burette to make up to 1000 c.c., and amount noted.

The same experiment was repeated, using a temperature of 110°F. The results are given below:

Temperature of $ZnCl_2$ and Water	Volume Water	$ZnCl_2$	No. c.c. Necessary to Make 1000 c.c.	Shrinkage
°F.	c.c.	c.c.	c.c.	Per Cent
70	952	48	6.5	0.65
110	952	48	6.9	0.69

The conclusions from the above may be briefly stated as follows:

When volumes of approximately 50% zinc chloride and water at the same temperature are mixed in the proportions required to give a 4% solution, and the resulting diluted solution is brought to the same temperature as the component parts, a shrinkage in volume occurs amounting to 0.65% of the total volume of the diluted solution. The shrinkage appears to vary somewhat with the temperature at which the dilution is carried out, an increase in temperature causing a slight increase in the amount of shrinkage and vice versa.

(3) IMPURITIES IN 50% ZINC CHLORIDE AND POSSIBLE RELATION TO HIGH GRAVITIES.—Frequently the 50% zinc chloride as delivered to the treating plants shows an unusually high specific gravity. The specific gravity of commercial 50% zinc chloride is always considerably higher than a theoretical 50% solution on account of the basic zinc in solution.

Hoping to shed some light on the cause of the unusually high gravities, the Committee decided to study the composition of representative samples of zinc chloride made by some of the leading manufacturers. With this object in view, 4 samples of zinc from 4 chemical companies, picked up on the open market, representing a composite sample of from 11 to 19 cars each, were obtained. These samples were analyzed by 3 laboratories, A, B, and C, quantitatively, and the results are given in the following table:

ANALYSES OF ZINC CHLORIDE.

SAMPLE	A			B			C			D		
Laboratory	a	b	c	a	b	c	a	b	c	a	b	c
Sp. Gr. at 15°C	1.580	1.568 at 29.6° C	1.580	1.600	1.590 at 29.6° C	1.604	1.620	1.603 at 25.5° C	1.617	1.580	1.570 at 25.5° C	1.581
	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
Zinc (soluble)	24.00		23.700	24.60		24.200	24.60		24.44	24.10		23.310
Same calculated to Zn Cl_2	50.02	49.20	49.420	51.27	49.30	50.440	51.27	50.90	50.95	50.12	48.20	48.600
Chlorine (soluble)	26.90		26.420	27.60		26.950	27.50		27.34	26.54		26.300
Fe	0.07	0.08	0.070	0.18	0.17	0.180	0.05	0.05	0.06	0.01	0.04	0.004
Mn	0.06			0.04			0.04			0.08		
Pb			0.005			0.005		trace	trace			0.020
CaO	0.02		0.040	0.01		0.020	0.02		0.04	0.29		0.318
MgO	0.26		0.230	0.02		0.090	0.02		0.03	0.47		0.427
Na_2O			0.050			0.090			0.75			trace
NaCl+K Cl	0.84			0.20			0.82			0.09		
NH_3		0.16	0.170		0.59	0.630		None	0.05			0.170
BaO			None			None			None			None
SO_3	0.27		0.270	0.98		0.950	0.52		0.49	0.01		0.110
Basicity (ZnO)	0.16		0.180	0.33		0.320	0.25		0.21	0.71		0.600
Organic									0.45			

A study of the analyses shows that aside from the basic zinc content the increased gravities are caused by the presence of small amounts of sulphates, alkali salts, lime and magnesia, etc. None of the impurities is present in sufficient quantity to raise the question as to whether its presence is objectionable from a timber preservative standpoint.

(4) METHODS OF ANALYSIS.—(a) Revision of standard ferro-cyanide method of analysis.

In 1917 PROCEEDINGS, under the heading "Insoluble (Basic Zinc Chloride)", line 3, page 280, change the word "Jena" to "Pyrex, or equivalent".

Under the heading of "Estimation of Zinc" two methods of analysis are given. The first is applicable only to chemically pure solution, or those in which iron and manganese are absent. The presence of either one will interfere with the reaction. As these two materials are known to be present in greater or lesser quantities in all commercial solutions, it is recommended that the part of the description of the method (page 281, line 6, 1917 PROCEEDINGS) beginning "To each of the aliquot, etc." and ending "is varied as follows" be omitted; also the last 5 words at the end of the second paragraph "as in the previous case", that the 2 paragraphs be combined into 1 and the following added to complete the final sentence, "with slow addition and vigorous stirring with potassium ferrocyanide solution, using uranium acetate as an external indicator. Note: bromine water may be substituted for hydrogen peroxide with equally good results".

(b) Tentative gravimetric method.

The Committee feels that the standard ferrocyanide method cannot be improved upon for an accurate method if a large number of analyses are to be made. There are times, however, when only an occasional analysis is desired. At such times a gravimetric determination of zinc may be somewhat more rapid than a volumetric method if new standard solutions have to be prepared and checked. The Committee has investigated several of the gravimetric methods and recommends as a tentative method the determination of zinc based on the precipitation of zinc phosphate. The whole analysis can be completed in 2 hours to 3 hours. The details of the method are as follows:

Gravimetric Determination of Zinc as Zinc Phosphate.

An accurately measured quantity of the zinc chloride solution is pipetted into a beaker. Add sufficient bromine water to impart a strong reddish brown color to the solution, and boil until all the bromine has been expelled. Add approximately 5 c.c. of a saturated solution of ammonium chloride for each 0.1 c.c. of zinc present, and then make the solution strongly ammoniacal, and filter off the iron.

Wash the precipitate with hot water 4 or 5 times, and boil the filtrate until the solution no longer smells of ammonia. Add 1 drop of methyl red and a large excess of sodium ammonium phosphate. Just neutralize the solution with acetic acid, and add 1 c.c. in excess. Heat the solution on the steam bath for a few minutes, or until the flocculent precipitate of zinc ammonium phosphate has become crystalline, and cool to room temperature.

Transfer the precipitate to a previously ignited and weighed gooch crucible, and wash the precipitate 3 or 4 times with hot water. Heat the crucible to a cherry red for a few minutes, cool, and weigh as zinc pyrophosphate, $Zn_2P_2O_7$ (Mw 304.8). The weight of the zinc pyrophosphate multiplied by 0.894 gives the equivalent weight of zinc chloride, or the weight of pyrophosphate multiplied by 0.429 gives the equivalent weight of zinc.

(c) Tentative volumetric method for the rapid, routine analysis of dilute zinc chloride solutions.

If a rapid method of analysis based on the direct determination of zinc rather than the indirect chloride method using silver nitrate solution is desired for analyzing plant-working solutions, the following volumetric method is offered as a tentative method:

Necessary apparatus:
Distilled water.
Beaker, or other receptacle capable of holding 400 c.c.
Glass rod.
One Mohr burette, 50 c.c. capacity.
25 c.c. graduate.
10 c.c. pipette.
N/10 standard hypo solution.
5% soluble starch solution.
10% potassium ferricyanide solution.
10% potassium iodide solution.
1 500 c.c. graduate.

This method is intended for solutions containing up to 5% zinc chloride. Free acid in any shape must not be allowed to get into the determination; therefore, solution must be neutral.

Take specific gravity of solution at 60°F. with suitable hydrometer. Pipette 10 c.c. of the zinc chloride solution into beaker or other receptacle holding 400 c.c. Add 20 c.c. of ferricyanide solution, then 10 c.c. of potassium iodide solution. Let stand 2 minutes with stirring. Add 300 c.c. of cold distilled water, then about 2 c.c. of starch. Titrate with 1/10 normal hypo, until blue fades to lemon yellow. Two drops will accomplish this end. With much iron present a slight greenish cast remains after the blue has faded, due to the presence of a small amount of prussian blue. A little practice will accustom the eye to this end which is sharp.

When absolutely neutral or slightly basic solutions containing small amounts of zinc chloride are treated with potassium ferricyanide and potassium iodide there is a definite amount of iodine set free. This liberated iodine may be estimated volumetrically by titrating the same with 1/10 normal hyposulphite of soda solution. It has been found by experience and experiment, working with known solutions of chloride of zinc, that the equivalent of 1 c.c. of N/10 hypo solution in zinc chloride is 0.0215 gram $ZnCl_2$. When the determination is carried on, as indicated in the method the following calculation will give the percentage of zinc chloride:

> Number of c.c. N/10 hypo times the zinc chloride equivalent of the hypo solution (0.0215 gram) times 100 divided by the number of c.c. of zinc chloride taken times the specific gravity equals per cent $ZnCl_2$.

This calculation is based on an empirical reaction found by practical experiment, and not on the basis of normality of solutions.

The N/10 sodium hyposulphite solution is prepared as follows:

> Weigh out 24.82 grams of crystallized, highest purity sodium hyposulphite. Dissolve in water. Make up to 1000 c.c. Standardize by titrating against standardized N/10 iodine, using starch indicator.

(5) SAMPLING ZINC CHLORIDE.—The following methods for sampling fused and liquid zinc chloride are recommended as tentative methods:

(a) Method of sampling fused zinc chloride at point of production.

Fused zinc chloride is in liquid condition when the drums are filled at the point of production. The easiest and most satisfactory way to sample same is as follows:

After stirring the contents of the drum with a galvanized iron rod to insure uniformity, a cold galvanized rod about 1 inch in diameter is plunged into the molten mass, held there for a few seconds and then withdrawn and allowed to drain. The rod will be covered with a coating of congealed zinc chloride. The solid chloride is knocked off the rod by means of a small zinc hammer, quickly collected and further reduced in size, if necessary, and introduced into a 4-oz. sample bottle. The bottle is then stopped with a cork covered with paraffined paper, and the head of the bottle, after stoppering, dipped into melted paraffine.

Three such samples should be taken from each drum and labeled to show drum number, date, and manufacturer. One sample is for the purchaser, the other 2 are to be retained by the manufacturer for a period of 90 days.

(b) Method of sampling liquid, or 50% zinc chloride.

As concentrated zinc chloride solution received in tank cars has no tendency to segregate into layers of different strengths, the usual bottle, or thief, method of sampling is satisfactory for obtaining a representative sample.

The apparatus consists of a bottle, or other container, attached to the end of an iron rod of sufficient length to reach to the bottom of the car. The bottle is lowered to the bottom of the car, and when at the bottom the stopper is withdrawn by means of a wire or spring. The sampler is then raised through the liquid at such a rate that the bottle will be full just as it reaches the surface. This will give a sample sufficiently representative of the contents of the car.

(6) **SPECIFIC GRAVITY TABLE.**—The following specific gravity table of zinc chloride solutions ranging from 0.39% to 70% is presented as a standard table for reference.

The solutions used in making up this table were made from electrolytic spelter and chemically pure hydrochloric acid, made up exactly to neutrality varying in gravity from 0.5° Bé to 70° Bé. The specific gravity determinations were made by means of a picnometer at 60°F., and are referred to water at 60°F. All work was done independently by 2 different men. All zinc determinations were made in duplicate by both men, both volumetrically and gravimetrically, and checked very closely. Gravimetric chlorine tests also checked very closely with the theoretical equivalents for the zinc. The results were plotted on coordinate paper, and the figures in the table were taken from the resulting curve. The degrees Beaumé were calculated from the gravities in the usual manner, using the formula:

$$\text{Deg. Bé} = 145 - \frac{145}{\text{Sp. Gr.}}$$

SPECIFIC GRAVITY TABLE FOR ZINC CHLORIDE.

(60° F. referred to water at 60° F.)

Beaumé	Sp. Gr. at 60/60° F.	$ZnCl_2$.	Beaumé	Sp. Gr. at 60/60° F.	$ZnCl_2$.
		Per cent			*Per cent*
0.5	1.0035	0.39	19.0	1.1508	16.03
1.0	1.0069	0.78	19.5	1.1554	16.50
1.5	1.0105	1.17	20.0	1.1600	17.00
2.0	1.0140	1.53	x20.35	1.1632	17.32
2.5	1.0175	1.90	20.5	1.1647	17.49
3.0	1.0211	2.30	21.0	1.1694	17.98
3.5	1.0247	2.68	21.5	1.1741	18.47
4.0	1.0284	3.04	22.0	1.1789	18.96
4.5	1.0320	3.42	22.5	1.1837	19.44
5.0	1.0357	3.82	23.0	1.1885	19.93
x5.08	1.0363	3.88	23.5	1.1934	20.40
5.5	1.0394	4.22	24.0	1.1983	20.90
6.0	1.0432	4.62	24.5	1.2033	21.36
6.5	1.0469	5.06	25.0	1.2083	21.86
7.0	1.0507	5.42	x25.14	1.2097	22.02
7.5	1.0545	5.89	25.5	1.2134	22.40
8.0	1.0584	6.30	26.0	1.2185	22.86
8.5	1.0623	6.70	26.5	1.2236	23.38
9.0	1.0662	7.12	27.0	1.2288	23.90
9.5	1.0701	7.50	27.5	1.2340	24.40
10.0	1.0741	7.97	28.0	1.2393	24.90
x10.16	1.0754	8.05	28.5	1.2446	25.40
10.5	1.0781	8.38	29.0	1.2500	25.92
11.0	1.0821	8.81	29.5	1.2554	26.42
11.5	1.0861	9.22	30.0	1.2609	26.90
12.0	1.0902	9.67	30.5	1.2664	27.43
12.5	1.0943	10.10	31.0	1.2719	27.95
13.0	1.0985	10.57	31.5	1.2775	28.43
13.5	1.1027	10.97	32.0	1.2832	28.97
14.0	1.1069	11.40	32.5	1.2889	29.46
14.5	1.1111	11.87	33.0	1.2946	29.98
15.0	1.1154	12.28	33.5	1.3004	30.47
x15.35	1.1184	12.59	34.0	1.3063	30.98
15.5	1.1197	12.70	34.5	1.3122	31.45
16.0	1.1240	13.20	35.0	1.3182	31.99
16.5	1.1284	13.65	x35.07	1.3189	32.00
17.0	1.1328	14.17	35.5	1.3242	32.46
17.5	1.1373	14.62	36.0	1.3303	32.96
18.0	1.1417	15.08	36.5	1.3364	33.46
18.5	1.1462	15.57	37.0	1.3426	33.97

(x) Specific gravity determinations and analyses made on these samples.

SPECIFIC GRAVITY TABLE FOR ZINC CHLORIDE (Concluded).

(60° F. referred to water at 60° F.)

Beaumé	Sp. Gr. at 60/60° F.	$ZnCl_2$.	Beaumé	Sp. Gr. at 60/60° F.	$ZnCl_2$.
		Per cent.			*Per cent*
37.5	1.3488	34.47	54.5	1.6022	52.11
38.0	1.3551	34.98	55.0	1.6111	52.65
38.5	1.3615	35.50	x55.05	1.6120	52.77
39.0	1.3679	36.00	55.5	1.6201	53.22
39.5	1.3744	36.51	56.0	1.6292	53.76
40.0	1.3810	37.01	56.5	1.6384	54.30
x40.15	1.3829	37.14	57.0	1.6477	54.81
40.5	1.3876	37.52	57.5	1.6571	55.38
41.0	1.3942	38.03	58.0	1.6667	55.93
41.5	1.4010	38.58	58.5	1.6763	56.47
42.0	1.4078	39.08	59.0	1.6860	57.00
42.5	1.4146	39.59	59.5	1.6959	57.51
43.0	1.4216	40.10	60.0	1.7059	58.03
43.5	1.4286	40.60	x60.13	1.7082	58.29
44.0	1.4356	41.14	60.50	1.7160	58.60
44.5	1.4428	41.61	61.0	1.7262	59.17
x44.99	1.4498	42.15	61.5	1.7365	59.70
45.0	1.4500	42.16	62.0	1.7470	60.20
45.5	1.4573	42.70	62.5	1 7576	60.73
46.0	1.4646	43.20	63.0	1.7683	61.34
46.5	1.4721	43.72	63.5	1.7791	61.89
47.0	1.4796	44.26	64.0	1.7901	62.40
47.5	1.4872	44.80	64.5	1.8012	62.90
48.0	1.4948	45.30	65.0	1.8125	63.46
48.5	1.5026	45.85	x65.11	1.8149	63.65
49.0	1.5104	46.38	65.5	1.8239	64.08
49.5	1.5183	46.90	66.0	1.8354	64.62
50.0	1.5263	47.40	66.5	1.8471	65.18
x50.14	1.5285	47.58	67.0	1.8590	65.80
50.5	1.5344	47.92	67.5	1.8710	66.40
51.0	1.5426	48.45	68.0	1.8831	66.99
51.5	1.5508	49.00	68.5	1.8954	67.52
52.0	1.5591	49.55	69.0	1.9079	68.18
52.5	1.5676	50.02	69.5	1.9205	68.70
53.0	1.5761	50.58	70.0	1.9333	69.40
53.5	1.5847	51.10	x70.05	1.9345	69.42
54.0	1.5934	51.62			

(x) Specific gravity determinations and analyses made on these samples.

In using the specific gravity table it must be remembered that the table is based on chemically pure zinc chloride, free from basic zinc. The gravity for a given per cent strength as shown in the table will be considerably lower than that of a commercial zinc chloride of the same soluble zinc content. For example, referring to table of analysis of zinc samples (page 6), Sample A shows an actual gravity at 60°F. of 1.580, whereas the table shows 1.5676; Sample C, 1.620 actual and 1.585 by the table.

If in connection with the use of the above gravity table it is desired to allow for temperature, corrections taken from the following table may be applied. This table is based on determinations made by placing solutions of various gravities in a hydrometer jar immersed in a water bath and raising the temperature of the solution until a total decrease in gravity of 3° Bé as shown by a hydrometer has taken place, temperature readings being made at 1° Bé intervals. The average number of degrees Fahrenheit required to cause a change of 1° Bé is taken as the reading for that particular strength. The table follows:

EFFECT OF TEMPERATURE ON GRAVITY.

Strength of Solution.	Degrees Fahrenheit Necessary to Produce Change in Gravity of 1° Bé.
° Bé.	*° F.*
5	42.0
10	34.0
15	34.0
20	30.3
25	30.3
30	30.3
35	30.3
40	30.3
45	30.3
50	33.0
55	36.0
60	37.0
65	37.0
70	42.0

(7) WORKING TABLE FOR PLANT USE.—(a) Preliminary data.

In order to work up a table for plant use it was first necessary to find the specific gravities of 1% to 5% solutions for various temperatures.

The basis of this investigation was chloride of zinc prepared from electrolytic zinc and chemically pure hydrochloric acid allowed to react to absolute neutrality as indicated by methyl orange. The specific gravities were taken by picnometer at 60°F. referred to water at 60°F.

Gravity Bé. at 60° F.	Zn.	Cl.	Cl. Calculated to $ZnCl_2$.	$ZnCl_2$ from Zn+Cl.
	Per cent	*Per cent*	*Per cent*	*Per cent*
1.35	0.49	0.52	1.01	1.01
2.43	0.90	0.96	1.86	1.86
3.66	1.36	1.47	2.83	2.83
4.69	1.75	1.88	3.63	3.63
6.14	2.29	2.49	4.78	4.78

DEGREES BEAUME, SPECIFIC GRAVITY AND PER CENT. ZINC CHLORIDE AT 60° F., 1% TO 5% ZINC CHLORIDE.

Beaumé.	Specific Gravity.	$ZnCl_2$.
Degrees		*Per cent*
1.35+	1.0093+	1.01+
1.94	1.0136	1.50
2.43+	1.0170+	1.86+
2.60	1.0183	2.00
3.23	1.0228	2.50
3.66+	1.0259+	2.83+
3.88	1.0275	3.00
4.52	1.0322	3.50
4.69	1.0335+	3.63+
5.16	1.0369	4.00
5.79	1.0416	4.50
6.14	1.0442+	4.78+
6.40	1.0462	5.00

+ Determined points.

In order that temperature corrections may be made for gravities taken with a hydrometer, experiments were made to determine the change of temperature necessary to produce a change of 1° Bé in solutions of zinc chloride of 1%, 2%, 3%, 4%, and 5% strength. The results are tabulated below:

Zinc Chloride.	Degrees Fahrenheit Required to Cause a Change of 1° Bé.
Per cent	*° F.*
1	50
2	50
3	49
4	45
5	42

In order to calculate the specific gravity of 1%, 2%, 3%, 4%, and 5% solutions at the various temperatures, it was necessary to determine the density of these solutions at various temperatures; that is, at 60°F., 100°F., 140°F., and 180°F. The density of these solutions was found by weighing equal volumes of air-free water and these respective solutions at identical temperatures. The weights for the unit volume of air-free water at the temperature at which the density was determined was taken from the table published by Marek, Scheel and Theissen, Physikalische Reichsanstalt, Germany. The results of these determinations are given below:

$ZnCl_2$.	At 60° F.	At 100° F.	At 140° F.	At 180° F.
Per cent				
1.01	1.0084	1.0025	0.9927	0.9794
1.86	1.0160	1.0100	0.9997	0.9861
2.83	1.0251	1.0188	1.0086	0.9952
3.63	1.0325	1.0258	1.0154	1.0017
4.78	1.0432	1.0362	1.0257	1.0118

From the above data with several interpolations, pounds per gallon, and pounds per cubic foot, were computed, using the following equivalents:

1 Gal. U. S. = 3785.43 grams.
1 Lb. = 453.59 "
1 Cu. Ft. = 7.48 gallons.

	Pounds per Gallon.				Pounds per Cubic Foot.			
$ZnCl_2$.	60° F.	100° F.	140° F.	180° F.	60° F.	100° F.	140° F.	180° F
Per cent	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs*
1.01+	8.416+	8.366+	8.242+	8.173+	62.949+	62.580+	61.965+	61.136+
1.86+	8.487+	8.429+	8.343+	8.229+	63.485+	63.049+	62.403+	61.557+
2.00	8.496	8.430	8.344	8.230	63.557	63.116	62.480	61.636
2.83+	8.554+	8.502+	8.417+	8.306+	63.991+	63.598+	62.961+	62.127+
3.00	8.567	8.514	8.428	8.317	64.086	63.689	63.051	62.211
3.63+	8.616+	8.561+	8.474+	8.360+	64.453+	64.035+	63.386+	62.530+
4.00	8.644	8.588	8.501	8.387	64.663	64.242	63.593	62.737
4.78+	8.705+	8.647+	8.560+	8.444+	65.114+	64.684+	64.029+	63.161+
5.00	8.721	8.664	8.577	8.561	65.239	64.807	64.152	63.284

+ Determined points.

(b) Working table in gallons and pounds.

The following table has been expanded from the above data for a plant-working table. To use it accurately solutions must be analyzed for their zinc content instead of depending on hydrometer readings.

POUNDS PER GALLON OF ZINC CHLORIDE AT DIFFERENT TEMPERATURES FOR WORKING SOLUTIONS.

Solution	60°F.	65°F.	70°F.	75°F.	80°F.	85°F.	90°F.	95°F.
1.0%	8.415	8.410	8.405	8.400	8.394	8.388	8.381	8.374
.1	.423	.418	.413	.407	.401	.395	.388	.381
.2	.431	.426	.420	.415	.408	.402	.395	.387
.3	.439	.434	.428	.422	.416	.409	.402	.394
.4	.447	.442	.436	.430	.423	.416	.409	.400
.5	.455	.450	.443	.437	.430	.423	.416	.407
.6	.463	.458	.451	.444	.437	.430	.423	.414
.7	.471	.466	.459	.452	.444	.437	.430	.420
.8	.479	.474	.467	.459	.452	.444	.437	.427
.9	.487	.482	.474	.467	.459	.451	.444	.433
2.0%	8.496	8.490	8.482	8.474	8.466	8.458	8.450	8.440
.1	.503	.497	.489	.482	.474	.466	.458	.448
.2	.510	.504	.496	.489	.482	.474	.466	.456
.3	.517	.511	.503	.497	.489	.481	.474	.467
.4	.524	.518	.510	.504	.497	.489	.482	.473
.5	.531	.525	.517	.512	.505	.497	.490	.481
.6	.538	.532	.524	.520	.513	.505	.498	.489
.7	.545	.539	.531	.527	.521	.513	.506	.497
.8	.552	.546	.538	.535	.528	.520	.514	.506
.9	.559	.553	.545	.542	.536	.528	.522	.514
3.0%	8.567	8.560	8.556	8.550	8.544	8.536	8.530	8.522
.1	.575	.568	.564	.558	.552	.544	.537	.529
.2	.582	.576	.572	.566	.559	.551	.545	.537
.3	.590	.584	.579	.573	.567	.559	.552	.544
.4	.598	.592	.587	.581	.574	.566	.560	.552
.5	.606	.600	.595	.589	.582	.574	.567	.559
.6	.613	.608	.603	.597	.589	.582	.574	.566
.7	.621	.616	.611	.605	.597	.589	.582	.574
.8	.629	.624	.618	.612	.604	.597	.589	.581
.9	.636	.632	.626	.620	.612	.604	.597	.588
4.0%	8.644	8.639	8.634	8.628	8.619	8.612	8.604	8.596
.1	.652	.647	.642	.636	.627	.620	.612	.604
.2	.659	.654	.649	.643	.635	.628	.619	.611
.3	.667	.662	.657	.651	.643	.635	.627	.619
.4	.675	.670	.664	.658	.651	.643	.635	.626
.5	.683	.678	.672	.666	.659	.651	.642	.634
.6	.690	.685	.680	.674	.667	.659	.650	.642
.7	.698	.693	.687	.681	.675	.667	.658	.649
.8	.706	.701	.695	.689	.683	.674	.665	.657
.9	.713	.708	.702	.696	.691	.682	.673	.664
5.0%	8.721	8.716	8.710	8.704	8.698	8.690	8.681	8.672

POUNDS PER GALLON OF ZINC CHLORIDE AT DIFFERENT TEMPERATURES FOR WORKING SOLUTIONS—(Continued).

Solution	100°F.	105°F.	110°F.	115°F.	120°F.	125°F.	130°F.	135°F.
1.0%	8.366	8.357	8.348	8.339	8.330	8.320	8.308	8.296
.1	.372	.363	.354	.345	.336	.326	.314	.302
.2	.379	.370	.360	.351	.342	.332	.320	.308
.3	.385	.376	.367	.357	.348	.338	.326	.315
.4	.392	.382	.373	.363	.354	.344	.332	.320
.5	.398	.389	.379	.369	.360	.350	.338	.327
.6	.404	.395	.385	.375	.366	.356	.344	.333
.7	.410	.401	.391	.381	.372	.362	.350	.339
.8	.417	.407	.398	.387	.378	.368	.356	.346
.9	.424	.414	.404	.393	.384	.374	.362	.352
1.0%	8.430	8.420	8.410	8.400	8.390	8.380	8.369	8.358
.1	.438	.429	.419	.409	.399	.389	.377	.367
.2	.447	.437	.427	.417	.407	.397	.386	.375
.3	.455	.446	.436	.426	.416	.406	.395	.384
.4	.464	.454	.444	.434	.424	.414	.404	.392
.5	.472	.463	.453	.443	.433	.423	.413	.401
.6	.480	.472	.462	.452	.442	.432	.421	.410
.7	.489	.480	.470	.460	.450	.440	.430	.418
.8	.497	.489	.479	.469	.459	.449	.439	.427
.9	.506	.497	.487	.477	.467	.457	.447	.435
3.0%	8.514	8.506	8.496	8.486	8.476	8.466	8.456	8.444
.1	.521	.513	.503	.493	.483	.473	.463	.451
.2	.529	.520	.510	.500	.490	.480	.470	.458
.3	.536	.528	.518	.508	.498	.488	.477	.465
.4	.544	.535	.525	.515	.505	.495	.484	.472
.5	.551	.542	.532	.522	.512	.502	.491	.479
.6	.558	.549	.539	.529	.519	.509	.498	.486
.7	.567	.556	.546	.536	.526	.516	.505	.493
.8	.573	.564	.554	.544	.534	.524	.512	.500
.9	.580	.570	.561	.551	.541	.531	.519	.507
4.0%	8.588	8.578	8.568	8.558	8.548	8.538	8.526	8.514
.1	.595	.586	.576	.566	.556	.546	.534	.522
.2	.603	.593	.583	.573	.563	.553	.541	.529
.3	.611	.601	.591	.581	.571	.561	.549	.537
.4	.618	.608	.598	.588	.578	.568	.556	.544
.5	.625	.616	.606	.596	.586	.576	.564	.552
.6	.633	.624	.614	.604	.594	.583	.572	.560
.7	.641	.631	.621	.611	.601	.591	.579	.567
.8	.648	.639	.629	.619	.609	.598	.587	.575
.9	.655	.646	.636	.626	.616	.606	.594	.582
5.0%	8.664	8.654	8.644	8.634	8.624	8.613	8.602	8.590

POUNDS PER GALLON OF ZINC CHLORIDE AT DIFFERENT TEMPERATURES FOR WORKING SOLUTIONS—Concluded.)

Solution	140°F.	145°F.	150°F.	155°F.	160°F.	165°F.	170°F.	175°F.	180°F.
1.0%	8.284	8.272	8.260	8.248	8.234	8.220	8.206	8.190	8.173
.1	.290	.278	.266	.253	.239	.225	.211	.196	.179
.2	.296	.284	.271	.259	.245	.231	.217	.201	.184
.3	.302	.289	.277	.264	.250	.236	.222	.207	.190
.4	.308	.295	.282	.270	.256	.242	.228	.212	.196
.5	.314	.301	.288	.275	.261	.247	.233	.218	.202
.6	.320	.307	.294	.280	.266	.252	.238	.224	.207
.7	.326	.312	.299	.286	.272	.258	.244	.229	.213
.8	.332	.318	.305	.291	.277	.263	.249	.235	.219
.9	.338	.324	.310	.297	.283	.269	.255	.240	.224
2.0%	8.344	8.330	8.316	8.302	8.288	8.274	8.260	8.246	8.230
.1	.353	.339	.325	.311	.297	.283	.269	.255	.239
.2	.362	.348	.334	.320	.306	.292	.278	.264	.247
.3	.370	.357	.344	.230	.316	.302	.287	.272	.256
.4	.379	.366	.353	.339	.325	.311	.296	.281	.265
.5	.388	.375	.362	.348	.334	.320	.305	.290	.273
.6	.397	.384	.271	.357	.343	.329	.314	.299	.282
.7	.406	.393	.380	.366	.352	.338	.323	.308	.291
.8	.414	.402	.390	.376	.362	.348	.332	.316	.299
.9	.423	.411	.399	.385	.371	.357	.341	.325	.308
3.0%	8.428	8.420	8.408	8.394	8.380	8.366	8.350	8.334	8.317
.1	.439	.427	.415	.401	.387	.373	.357	.341	.324
.2	.446	.434	.421	.408	.394	.380	.364	.348	.331
.3	.453	.440	.428	.414	.400	.386	.371	.355	.338
.4	.460	.447	.435	.421	.407	.393	.378	.362	.345
.5	.467	.454	.442	.428	.414	.400	.385	.369	.352
.6	.474	.461	.448	.435	.421	.407	.392	.376	.359
.7	.481	.468	.455	.442	.428	.414	.399	.383	.366
.8	.488	.474	.462	.448	.434	.420	.406	.390	.373
.9	.495	.481	.468	.455	.441	.427	.413	.397	.380
4.0%	8.501	8.488	8.475	8.462	8.448	8.434	8.420	8.404	8.387
.1	.509	.496	.483	.470	.456	.442	.427	.411	.394
.2	.516	.503	.490	.477	.463	.449	.435	.419	.402
.3	.524	.511	.498	.485	.471	.457	.442	.426	.409
.4	.531	.518	.505	.492	.478	.464	.450	.434	.417
.5	.539	.526	.513	.500	.486	.472	.457	.441	.424
.6	.547	.533	.521	.508	.494	.480	.464	.448	.431
.7	.554	.541	.528	.515	.501	.487	.472	.456	.439
.8	.562	.549	.536	.523	.509	.495	.479	.463	.446
.9	.569	.556	.543	.530	.516	.502	.487	.471	.454
5.0%	8.577	8.564	8.551	8.538	8.524	8.510	8.494	8.478	8.461

(8) METHODS OF FIGURING ZINC CHLORIDE DILUTIONS AND CONCENTRATIONS.—(a) Discussion.

In handling zinc chloride in the treating plant it is necessary to make proper dilutions and concentrations. This work is simplified by using either of the 2 methods described in the following discussion:

Formula Method for Dilution and Concentration Explained.

A formula is derived for each possible case for making dilutions and concentrations from the simple fact that the amount of zinc chloride used is equal to the amount of zinc chloride in the resulting solution. To use the formulae select the one to suit the case in question and substitute for the symbols their values and solve for the unknown.

For convenience we shall use the following symbols to be used alike in all formulae to follow later:[*]

A = Weight in lbs. of *above treating* solution.
a = Per cent of *above treating* solution.
B = Weight in lbs. of *below treating* solution.
b = Per cent of *below treating* solution.
C = Weight in lbs. of *concentrated* solution.
c = Per cent of *concentrated* solution.
F = Weight in lbs. of *fused* $ZnCl_2$.
f = Per cent of *fused* $ZnCl_2$.

Tt = Weight in lbs. of *treating* solution.
t = Per cent of *treating* solution.
W = Weight in lbs. of *water*.

Therefore:

Aa = Weight of zinc chloride dissolved in the *above treating* solution.
Bb = Weight of zinc chloride dissolved in the *below treating* solution.
Cc = Weight of zinc chloride dissolved in the *concentrated* solution.
Ff = Weight of zinc chloride in the *fused* $ZnCl_2$.
Tt = Weight of zinc chloride dissolved in the *treating* solution.

Rectangle Method for Dilution and Concentration Explained.

The figures expressing the percentage concentration of 2 solutions are written in the 2 left-hand corners of a rectangle and the figure expressing the desired concentration is placed on the intersection of the 2 diagonals of this rectangle. Now, subtract the figure on the diagonals, the smaller from the larger, and write the result at the other end of the respective diagonal. These figures then indicate what quantities of the solutions, whose concentrations are given on the other end of the respective horizontal line, must be taken to obtain a solution of the desired concentration.

For example: To make a 3.5% zinc chloride treating solution from a 50% concentrated solution and water we prepare Fig. 1, and find that we have to take 3.5 parts of the 50% solution and 46.5 parts by weight of the water to obtain 50 parts by weight of a 3.5% solution.

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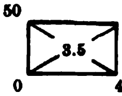
[*] The terms "above" and "below" signify solutions stronger and weaker than strength of working solution desired.



3.5 parts by weight of 50% solution.

46.5 parts by weight of water.

50.0 parts by weight of 3.5% solution.

Fig. 1.

(b) Cases and concrete examples:

Case 1.—*Dilution* of *concentrated* solution with *water* to make a *definite amount* of *treating* solution.

Problem.—How many gallons of a 50% (concentrated) solution must be diluted with water to make 10,000 gals. of a 3.5% (treating) solution at 160°F.?

Formula Method.

$$Cc = Tt$$

Therefore,

$$C = \frac{Tt}{c}$$

substituting,

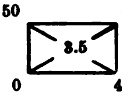
10,000 × 8.414 (wt. 1 gal. of 3.5% at 160° F.) = 84,140 lbs.

$$C = \frac{84{,}140 \times .035}{.50}$$

C = 5889.8 lbs.

5889.8 lbs. ÷ 13.0824 (wt. 1 gal. 50% at 60° F.) = 450.28 gals. at 60° F.

Rectangle Method.



3.5 parts by weight of 50% solution.

46.5 parts by weight of water.

50.0 parts by weight of 3.5% solution.

10,000 × 8.414 (wt. 1 gal. of 3.5% at 160° F.) = 84,140 lbs.

50 : 3.5 : : 84,140 : C

50 C = 84,140 x 3.5

C = 5889.8 lbs.

5889.8 lbs. ÷ 13.0824 (wt. 1 gal. 50% at 60° F.) = 450.28 gals. at 60° F.

Case 2.—*Dilution* of a *definite amount* of *concentrated* solution with *water*, thus forming a greater amount than this of *treating* solution.

Problem.—How many gallons of water must be added to 450.28 gals. of 50% (concentrated) solution to form 3.5% (treating) solution at 160°F.?

Formula Method.

$$Tt = Cc$$

but

$$T = W + C$$

substituting new value for T.

$$(W+C)t = Cc$$
$$Wt + Ct = Cc$$
$$Wt = Cc - Ct$$
$$W = \frac{C(c-t)}{t}$$

substituting,

450.28 × 13.0824 (wt. 1 gal. 50% at 60° F.) = 5889.8 lbs.

$$W = \frac{5889.8\ (.50 - .035)}{.035}$$

W = 78250.20 lbs.

78250.20 ÷ 8.3455 = 9376.21 gals. at 60° F.

Rectangle Method.

50 3.5 parts by weight of 50% solution.

0 46.5 parts by weight of water.

50.0 parts by weight of 3.5% solution.

450.28 × 13.0824 (wt. 1 gal. 50% at 60° F.) = 5889.8 lbs.

3.5 : 46.5 : : 5889.8 : W

3.5 W = 5889.8 × 46.5

W = 78250.20 lbs.

78250.20 ÷ 8.3455 (wt. 1 gal. water at 60° F.) = 9376.21 gals. at 60° F.

Case 3.—The addition of *concentrated* solution to a *definite amount* of *water*, thus producing a greater amount of *treating* solution.

Problem.—How many gallons of 50% (concentrated) solution must be added to 9376.21 gals. of water to produce a 3.5% (treating) solution at 160°F.?

Formula Method:

$$Cc = Tt$$

but

$$T = W + C$$

substituting the new value for T

$$Cc = (W + C)t$$
$$Cc = Wt + Ct$$
$$Cc - Ct = Wt$$
$$C(c - t) = W$$
$$C = \frac{Wt}{(c - t)}$$

substituting

9376.21 × 8.3455 (wt. 1 gal. water at 60° F.) = 78250.20 lbs.

$$C = \frac{78250.20 \times .035}{.50 - .035}$$

C = 5889.80 lbs.

5889.8 ÷ 13.0824 (wt. of 1 gal. 50% at 60° F.) = 450.28 gals. at 60° F.

Rectangle Method.

50 3.5 parts by weight of 50% solution.

0 46.5 parts by weight of water.

50.0 parts by weight of 3.5% solution.

9376.21 × 8.3455 (wt. 1 gal. water at 60° F.) = 78250.20 lbs.

46.5 : 3.5 : : 78250.20 : C.

46.5 C = 78250.20 x 3.5

C = 5889.80 lbs.

5889.80 ÷ 13.0824 (wt. 1 gal. 50% at 60° F.) = 450.28 gals. at 60° F.

Case 4.—Dilution of an *above treating* solution with *water* producing a greater amount of *treating* solution.

Problem.—How many gallons of water at 60°F. must be added to 10,000 gals. of a 4% *above treating* solution at 160°F. to make a 3.5% *treating* solution at 160°F.?

Formula Method.

$$Tt = Aa$$

but

$$T = W + A$$

substituting a new value for T

$$(W+A)t = Aa$$
$$Wt + At = Aa$$
$$Wt = Aa - At$$
$$W = \frac{A(a-t)}{t}$$

substituting

10,000 × 8.448 (wt. 1 gal. 4% solution at 160° F.) = 84480 lbs.

$$W = \frac{84480\ (.04 - .035)}{.035}$$

$W = 12068.57$

12068.57 + 8.3455 (wt. 1 gal. water at 60° F.) = 1446.11 gals. at 60° F.

Rectangle Method.

4.0 3.5 parts by weight of 4% solution.

0 .5 parts by weight of water.

4.0 parts by weight of 3.5% solution.

10,000 × 8.448 (wt. 1 gal. 4.0% at 160° F.) = 84480 lbs.

3.5 : 5 : : 84480 : W

3.5 W = 84489 × .5

W = 12068. 57 lbs.

12068.57 + 8.3455 = 1446.11 gals. at 60° F.

Case 5.—*Concentration* of a definite amount of *below treating* solution by the addition of a *concentrated* solution producing a greater amount of *treating* solution.

Problem.—How many gallons of 50% (concentrated) solution must be added to 10,000 gals. of a 3.0% (*below treating*) solution at 160°F. to make a 3.5% (treating) solution at 160°F.?

Formula Method.

$$Cc + Bb = Tt$$

but

$$T = C + B$$

substituting new value for T.

$$Cc + Bb = (C+B)t$$
$$Cc + Bb = Ct + Bt$$
$$Cc - Ct = Bt - Bb$$
$$C(c-t) = B(t-b)$$

therefore

$$C = \frac{B(t-b)}{(c-t)}$$

substituting

10,000 × 8.380 (wt. 1 gal. 3.0% at 160° F.) = 83,800 lbs.

$$C = \frac{83800\ (.035 - .03)}{(.50 - .035)}$$

C = 901.07 lbs.

901.07 + 13.0824 = 61.23 gals. at 60° F.

Rectangle Method.

50 .5 parts by weight of 50% solution.

3.0 46.5 parts by weight of 3.0% solution.

47.0 parts by weight of 3.5% solution.

10.000 × 8.380 (wt. 1 gal. 3.0 % at 160° F.) = 83800 lbs.

46.5 : .5 : : 83800 : C

46.5 = 83800 × .5

C = 901.07 lbs.

901.07 + 13.0824 (wt. 1 gal. 50 %) = 61.23 gals. at 60° F.

Case 6.—*Preparation* of a *treating* solution from a *definite amount* of *fused* zinc chloride.

Problem.—How many gallons of a 3.5% (treating) solution at 160°F. can be made from 1,000 lbs. of a 95% fused zinc chloride?

Formula Method.

$$Tt = Ff$$

therefore

$$T = \frac{Ff}{t}$$

substituting

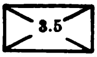
$$T = \frac{1000 \times .95}{.035}$$

$$T = 27142.86 \text{ lbs.}$$

27142.86 ÷ 8.414 (wt. 1 gal. 3.5% at 160° F.) = 3225.91 gals. at 160° F.

Rectangle Method.

95 3.5 parts by weight of 95% zinc chloride.



0 91.5 parts by weight of water.

95.0 parts by weight of 3.5% solution.

$$3.5 : 95 :: 1000 : T$$
$$3.5\ T = 1000 \times 95$$
$$T = 27142.86 \text{ lbs.}$$

27142.86 ÷ 8.414 (wt. 1 gal. 3.5% at 160° F.) = 3225.91 gals. at 160° F.

Case 7.—*Preparation* of a *definite amount* of a *treating* solution from *fused* zinc chloride.

Problem.—How many pounds of 95% fused zinc chloride are necessary to make 3225.91 gals. of a 3.5% (treating) solution at 160°F.?

Formula Method.

$$Ff = Tt$$

therefore

$$F = \frac{Tt}{f}$$

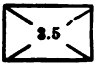
3225.91 × 8.414 (wt. 1 gal. 3.5% at 160° F.) = 27142.86 lbs.

$$F = \frac{27142.86 \times .035}{.95}$$

$$F = 1000 \text{ lbs.}$$

Rectangle Method.

95 3.5 parts by weight of 95% zinc chloride.



0 91 5 parts by weight of water.

95.0 parts by weight of 3.5% solution.

3225.91 × 8.414 (wt. 1 gal. 3.5% at 160° F.) = 27142.86 lbs.

$$95 : 3.5 :: 27142.86 : F$$
$$95\ F = 27142.86 \times 3.5$$
$$F = 1{,}000 \text{ lbs.}$$

(9) METHOD OF FIGURING VOLUMETRIC ABSORPTION.—Volumetric absorption is the ratio between the volume of solution absorbed in treatment and the volume of the timber treated; in other words, the cubic feet of solution injected divided by the cubic feet of wood treated. This may be expressed in a formula, as follows:

$$\% \text{ Vol. absorption} = \frac{\dfrac{\text{Gallons of solution}}{7.48}}{\text{Cu. ft. timber in charge}} \times 100$$

(10) VISUAL METHOD FOR DETERMINING PENETRATION.—The Committee recommends for adoption as a standard and printing in the MANUAL, the visual method for determining the penetration of zinc chloride in treated timber of Galen Wood, described by him in a paper read before the American Wood-Preservers' Association convention in Chicago in 1920, and published in the 1920 PROCEEDINGS, page 182, entitled "Iodine-Potassium Ferricyanide-Starch Color Reaction Test for Determining Zinz Chloride Penetration". The method is as follows:

> CHEMICAL PRINCIPLE.—The iodine method for determining zinc chloride penetration is based on the principle that zinc ferricyanide liberates free iodine and free iodine in turn gives a dark blue stain with starch solution. It is evident then that the zinc chloride that has been injected into the ties will react with potassium ferricyanide, making zinc ferricyanide, and this in turn will liberate free iodine and give the blue stain as stated above. It is a well-known fact that free iodine can be detected in very minute quantities with starch solution, and can be made a very delicate test, such as detecting minute amounts of zinc chloride in treated ties.
>
> PREPARATION OF SOLUTIONS.—Prepare about 200 c.c. each of the following stock solutions, to be kept separate until used:
>
> 1% solution of potassium ferricyanide.
> 1% solution of potassium iodide.
> 5% solution of soluble starch.
>
> In making a starch solution, be sure to boil until the starch is in solution, otherwise the reaction will not be satisfactory. A starch solution will not keep long, and must not be used when it begins to sour. Be sure the starch solution is reasonably fresh.
>
> METHOD OF APPLICATION.—The disc of wood to be tested should be reasonably dry. Mix 10 c.c. each of the 3 stock solutions, and pour into a good atomizer. A De Vilbiss No. 30 has been found satisfactory. Spray the disc of wood evenly all over. The reaction between the zinc chloride and the spraying solution will instantly cause the treated wood to turn a deep blue, while the untreated part will retain its original color. This method is a positive test. Should the color fade, repeat the process.

III.—Effect of Zinc Chloride Treatment on Strength of Wood.

The Committee presents as information 3 papers bearing on this subject:

"Experiments on the Strength of Treated Timber", by W. K. Hatt; Forest Service Circular No. 39. (Exhibit A.)

"The Effect of the Zinc Chloride Process of Preservation on the Strength of Structural Timber", by H. B. Luther. (Exhibit B.)

"Results of Some Tests of the Effect of Zinc Chloride on the Strength of Wood", by T. R. C. Wilson and Ernest Bateman. (Exhibit C.)

The first of these papers is given in abstract only and is limited to those portions dealing with zinc chloride. The plan for this work was drawn up by Dr. Hermann von Schrenk and Dr. W. K. Hatt, and published in 1906 under the authorship of the latter. The original paper considers not only the effect of zinc chloride treatment, but also that of steaming and creosoting.

The second paper is an original contribution by Prof. H. B. Luther, of the Massachusetts Institute of Technology, and the third is an original paper by Messrs. Wilson and Bateman of the Forest Service, describing tests made by them at the Madison laboratory.

CONCLUSION.

The 3 papers taken together seem to indicate that:

(1) The treatment of wood with the usual strength of zinc chlo-solutions seems to have but little permanent effect upon the strength of wood in bending even 5 years after treatment, provided the temperature of the wood during that time is not excessively high.

(2) There seems to be a slight permanent decrease in the resistance of zinc-treated wood to shock even at the normal temperatures. This decrease seems to be greater with greater absorptions of zinc chloride.

(3) At temperatures somewhat higher than the normal there may be a considerable reduction in all strength values.

Exhibits B and C are presented as separate papers. Exhibit A is given herewith.

Digest of "Experiments on the Strength of Treated Timber."*

MATERIALS USED.—The material for the experiments was railroad ties 11 ft. long. One "8-ft." section of each tie was put through the particular treatment, the untreated section, 3 ft. long, was used for control test pieces.

TESTS OF SMALL PIECES.—From each tie 12 pieces were taken, 4 from the control section and 8 from the treated section. All of these pieces were 2 inches by 2 inches in cross-sections and 36 inches long, with one side parallel to the direction of the annual rings and the other at right angles to it. After the bending tests had been made on these pieces, smaller pieces, 2 inches by 2 inches in cross-section and 4 inches long were cut from their ends and used in compression and shearing tests. The experiments on any run were based on 4 ties marked A, B, C and D, and yielded 36 tests per tie.

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*Forest Service Circular No. 39.

TESTS OF FULL-SIZED TIES.—In addition to the tests on small pieces, the strength of full-sized ties in bending and in compression, both parallel and at right angles to grain, was obtained, as well as the capacity of the wood to hold a spike. The ties used were 8 ft. long. The entire tie was treated and afterwards tested in full size. In the bending tests under a static load the ties were supported on a span of 80 inches and loaded at the third points of the span. Short sections of the ties were used for tests to determine the resistance against compression parallel to grain, against compression at right angles to grain (which is similar to that produced on a tie by the base of a rail) and against the force withdrawing a spike.

In the tests of compression at right angles to grain the width of the tool equaled that of the base of an 80-lb. rail of the standard of the American Society of Civil Engineers. The force necessary to cause the yielding of the wood was measured. Both screw spikes and common spikes were driven into the tie, and the force necessary to pull them out directly along their length was measured. Any common spike was driven but once, since it was found that the resistance against pulling diminished when the spike was redriven into new wood.

The weight of the tie before treating, after treating, and at the time of test was determined. The physical characteristics of the wood, such as per cent of sap, rate of growth, shakes, knots, and moisture content, were also recorded.

Impact tests were made on certain of the full-sized ties.

METHODS OF TEST.—The methods of test were those standard in the Forest Service, which are fully described in Circular No. 38.*

The methods of measurement were precise. Great care was taken to render the results accurate and reliable. No measurements or other data that might be of future value were omitted.

The data taken included the moisture conditions, specific gravity, rate of growth, sap and heart, and in the case of full-sized ties the weight at various stages, the defects, such as knots, checks, crooked grain, rate of growth throughout the cross-section, penetration of preservative fluid, discoloration due to steaming, etc. During the cylinder operations at St. Louis records were kept of the temperature to which the timbers were subjected at all stages, the amount of moisture lost or gained, and the amount of preservative absorbed, as indicated by the gross weight and subsequent chemical analysis of the test pieces.

RESULTS.—The results of the tests in so far as they apply to zinc chloride treatments are given in the accompanying table. The strength data are given in percentage of the strength of similar wood steamed for the same length of time at the same pressure and temperature.

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*Instructions to Engineers of Timber Tests, Circular No. 38, Forest Service, U. S. Department of Agriculture.

CONCLUSION.—The author drew the following conclusion: The presence of zinc chloride will not weaken wood under static loading, although the indications are that the wood becomes brittle under impact.

STRENGTH TESTS ON GREEN LOBLOLLY PINE TREATED WITH ZINC CHLORIDE SOLUTIONS.

Strength of Zinc Chloride Solution.	Cylinder Condition During Steams.			Strength.			
				Static.		Impact.	
	Period, Hours.	Pressure lbs. per Sq. In.	Temperature. Degrees F.	Bending per cent of Steamed Untr't'd Wood.	Compression Parallel vs. Grain.	Bending.	Average of 3 tests.
Specimens 2 x 2 tested immediately after treatment.							
2.5	4	20	249	98.1	107.8	88.4	97.9
10.0	4	20	255	105.0	112.4	84.2	100.5
Specimens 2 x 2 tested air dry.							
2.5	4	20	249	87.4	92.8	113.8	98.0
3.5	4	20	246	97.4	95.2	92.7	95.1
5.0	4	20	246	99.8	96.7	78.9	91.8
10.0	4	20	255	100.1	100.4	74.8	91.8
Specimens 2 x 2 treated, dried and resoaked and then tested.							
2.5	4	20	249	....	....	100.4	....
3.5	4	20	246	....	....	99.0	....
5.0	4	20	246	....	....	100.0	....
10.0	4	20	255	....	....	102.0	....
Ties—seasoned—treated, reseasoned—tested.							
2.5	4	20	258	79.7	65.1	68.6	69.5

IV.—Sampling Creosote Oil in Tank Cars for Water Determination.

The Committee received instruction from the Executive Committee to "complete investigations on sampling of tank cars". This was understood to refer to creosote oil.

The investigation of this subject has been in the hands of a joint committee since 1916, consisting of representatives of this Association, the American Railway Engineering Association, and the American Society for Testing Materials. The joint committee submitted an extensive report to this Association last year (see 1920 PROCEEDINGS, page 31). This report contained a recommendation for a standard method of sampling creosote oil in tank cars where an excessive amount of water is known or suspected of being present. The chairman of the then Committee on Preservatives recommended that this method be accepted as information, and made the request that the method be used by as many as possible during the year so that if experience with its use justified it could be submitted to the Association for adoption as a standard at its next convention.

This matter was considered at the first meeting of the Committee, and it was agreed that the method of sampling as recommended last year should be thoroughly tried out at treating plants receiving oil and that data on actual experience with its use should be collected. To this end the chairman was instructed to send out a circular letter with report form attached to creosote plant operators, requesting them to give the method a thorough trial and to report their experience with it on the blank form provided for the purpose.

In compliance with these instructions the chairman sent out letters and report forms to a number of the larger plant operators. The issuance of this letter, soliciting cooperation had to be delayed, awaiting the publication and distribution of the 1920 PROCEEDINGS in which was to appear the only available description and discussion of the method. Before oil consumers could be asked to give the method a trial it was, of course, necessary that a full description be accessible to them. On account of its length and the number of tables and diagrams it contains, the report could not be made available except through the PROCEEDINGS. As the latter was not distributed until late in October, 1920, the letter was not sent out until November 5. To date no replies have been received, time being too short. The Committee, therefore, cannot make a report on actual experience or use of this method of sampling and is in no position to recommend its adoption as a standard.

It is recommended that the Committee for next year be instructed to continue work on this subject, and to definitely report on the advisability of adopting this method of sampling tank cars as a standard.

V.—Vertical Retort Tars.

In view of the increasing installation of vertical retorts for the distillation of coal in the manufacture of illuminating gas and the attendant increase of tars from this source, the Committee believes that the Association should take cognizance of this recent development and inform itself of the possibilities of this potential source of preservative oils. It is now generally recognized that the future development in coal distillation will be in the direction of low-temperature distillation, and the indications are that low-temperature tars will appear on the market in yearly increasing quantities. Such being the case, the possibility of the utilization of such tars and the oil derived from them for preservative purposes cannot be ignored.

Having the above considerations in mind, the Committee has gotten together as much information and data as were available, hoping that a study of the material presented will be the starting point for further investigations by future committees. The progress of this new development should be closely followed by the Committee on Preservatives so that when this new source of preservative material is produced in sufficient quantities to become of economic importance, the Association will be in a position to adopt a definite policy as to its use as a suitable and safe timber preservative.

In line with this policy of preparedness, the Committee has made arrangement for a service-test with vertical-retort tar. The Forest Products Laboratory has agreed to treat 100 ties with vertical-retort-tar oil, and to place them in the cooperative test-track on the Chicago, Milwaukee and St. Paul Railroad. The United Gas Improvement Company of Philadelphia, through Mr. W. H. Fulweiler, has agreed to furnish a quantity of vertical-retort-tar distillate, sufficient for the treatment of these ties.

The following information on vertical-retort tar is submitted to the association as information:

VERTICAL-RETORT TAR.—At the present time the total daily capacity of vertical installations of all kinds, that is, Glover-West, Woodall-Duckham, and U. G. I. types, is slightly over 19,000,000 cu. ft. per day. This is equivalent to a production of between 9,000,000 gals. and 10,000,000 gals. per year of vertical-retort tar. With the existing high cost of gas oil, and the probability that it will continue high for a number of years, a very considerable number of plants are considering the installation of more coal gas capacity, and plans are drawn for the installation of 85,000,000 cu. ft. of vertical retorts. This will bring up the production to between 40,000,000 gals. and 50,000,000 gals. of tar per year.

A number of these plants would have been started this year, but for the fact that the financial situation is such that Public Service corporations are at present unable to borrow money at anything approaching reasonable terms. It is believed, however, that as soon as the present financial situation has eased these installations will be made.

Coke-oven tar in its general characteristics resembles on one hand coke-oven tar and on the other, blast-furnace tar. Vertical-retort tar is more fluid that coke-oven tar, and is comparatively low in free carbon. Naphthalene is practically absent. Its tar acid content and sulphonation residue are high.

Creosote oil made from vertical-retort tar on fractionation yields fractions which fall below the specific gravity requirements of the

A. W.-P. A. specifications, but in general are well above the specific gravity range of oil derived from water-gas tar.

Certain vertical-retort tars yield oils having gravities of fractions as low as water-gas oil. The latter tars are unusual, however, and are produced in limited quantities.

In the following tables analyses of vertical-retort tars and oils are shown. Table 1 shows the analysis of tars derived from 3 well-known types of installation. Table 2 shows more complete analyses of 3 sample of vertical tar. Table 3 gives analyses of distillate creosote oil made from the 3 tars whose analyses are shown in Table 2. Table 4 shows a comparison of vertical-retort tars with water-gas tars as to specific gravity of certain fractions.

TABLE 1.—ANALYSES OF TARS FROM THREE TYPES OF INSTALLATION.

System.	Woodall Duckham.	Dessau.	U. G. I.
Sp. gr. at 38°/15.5° C.	1.1422	1.1750	1.1300
Free carbon	12.5% by wt.	25.6%	5.5%
Unsulphonated material	10.7 " "	....	2.3
Distillation to 210° C.	1.5 by vol.	0.1 by vol.	7.5 by vol.
235° C.	6.3 " "	1.6 " "	17.5 " "
315° C.	22.1 " "	17.7 " "	39.0 " "
355° C.	33.0 " "	29.8 " "	50.2 " "
Coke	31.5 " wt.	31.3 " wt.	23.2 " wt.
Tar acids	13.9 " vol.	10.0 " vol.	13.2 " vol.
Naphthalene	0.1 lb. per gal.	0.04 lb. per gal.	0.12 lb. per gal.
Sp.gr.,235°C.-315°C.at 38°/15.5°C.	0.9928	1.0356	1.0010
Sp.gr.,315°C.-355°C.at 38°/15.5°C.	1.0284	1.0858	1.0610

TABLE 2.—ANALYSES OF THREE VERTICAL-RETORT TARS.

	A	B	C
Water in samples as received	1.6	3.0	1.4
Sp. gr. at 25°/25°C.	1.166	1.138	1.166
Sp. gr. at 38°/38°C.	1.159	1.128	1.160
Carbon, CS_2	9.0	3.2	7.7
Carbon, hot C_6H_6	10.4	2.8	9.1
Tar acids, orig. tar, per cent volume	6.9	10.3	4.3

Distillation, dry tar.	A				B				C			
	Per Cent.	Sp. Gr. 38°/15.5° C.	Sulph. Residue.	Refractive Index.	Per Cent.	Sp. Gr. 38°/15.5° C.	Sulph. Residue.	Refractive Index.	Per Cent.	Sp. Gr. 38°/15.5° C.	Sulph. Residue.	Refractive Index.
Oil to 170° C.	0.2				0.5			1.5170	0.5			1.5385
170° C.-210° C.	0.7	0.979	2.5	1.5460	5.0	0.975	5.4	1.5430	1.2	0.993	1.5	1.5535
210° C.-235° C.	4.5	1.009	2.6	1.5560	8.7	1.003	4.0	1.5[illegible]05	2.6	1.015	2.0	1.5655
235° C.-270° C.	8.0	1.020	2.6	1.5760	13.0	1.023	2.8	1.5805	8.7	1.036	1.8	1.5820
270° C.-300° C.	9.0	1.042	2.6	1.6002	5.3	1.047	2.0	1.6045	4.6	1.057	1.0	1.6045
300° C.-315° C.	3.6	1.064	2.4	1.6188	3.3	1.065	1.6	1.6180	3.3	1.072	1.0	1.6195
315° C.-355° C.	17.0	1.099	2.4	1.6415	12.5	1.087	1.2	1.6354	15.3	1.091	0.5	1.6440
355° C.-Coke	21.0	1.151	0.8	1.6440	31.0	1.165	0.5	1.6425	35.0	1.148	Trace	1.6450
Total	64.0				79.3				71.2			

TABLE 3.—ANALYSES OF CREOSOTE OILS MADE FROM VERTICAL-COAL TARS.

	A		B		C	
Sp. gr. at 38°/15/5° C.	1.092	1.040	1.084	1.041	1.105	1.043
Carbon, hot C_6H_6	0.07	......	0.06	......	0.10	......
Coke, per cent weight	1.7	......	1.6	......	1.8	......
Distillation:						
Total oil to 210° C.	0.32	1.9	3.26	3.9	0.85	3.4
235° C.	3.67	11.4	16.04	24.0	3.55	19.4
315° C.	34.20	67.9	40.30	66.8	25.06	76.6
355° C.	52.07	90.4	51.25	88.1	41.58	96.7
Float-test residue above 355°C. at 70°C.	31.5 Min.	28.5 Min.	34 Min.	27.5 Min.	29 Min.	......
Sp. gr., 38°/15.5° C.						
235° C.–315° C.	1.024	1.031	1.025	1.023	1.031	1.035
315° C.–355° C.	1.076	1.080	1.073	1.075	1.073	1.093

TABLE 4.—TESTS ON VERTICAL-GAS-RETORT TARS IN COMPARISON WITH WATER TARS AS TO SPECIFIC GRAVITY OF CERTAIN FRACTIONS.

Source of Tar.	Pitch Made.		Oil Yield.	Retort Distillation.			Specific Gravity at 38°/15.5° C.		
	M. P.			235° C	315° C	355° C	235° C 315° C	315° C 355° C	Original Oil
	Deg.	%	%	%	%	%			
Vertical Retort No. 1	150	40	59	32	71	89	1.026	1.090	1.032
Vertical Retort No. 2	150	38	61	28	65	84	1.025	1.091	1.037
Water Gas No. 1 ...	150	35	64*	28	76	93	0.977	1.040	0.976
Water Gas No. 2 ...	150	44	55	15	71	91	0.970	1.029	0.983
Water Gas No. 3 ...	150	33	66	25	77	93	0.977	1.041	0.97
Vertical Retort No. 3	137	41	58	27	63	93	1.025	1.091	1.044
Vertical Retort No. 4	62	73	26	......	......	......	1.041	....	....
Vertical Retort No. 5	80	63	36	......	......	......	1.014	....	....
Vertical Retort No. 6	125	53	46	......	......	......	1.003	....	....
Vertical Retort No. 7	122	56	43	......	......	......	1.018	1.089	....

*Distilled in small works still; all other tars distilled in laboratory still.

CONCLUSION.—While it is true that vertical-retort tar is a coal tar, and the oil made from it is a coal-tar creosote, this material cannot be accepted as standard creosote oil. It may be as good and even better, but its value as a preservative is as yet unknown. It must stand on its own merits, which can only be determined by actual use and service tests.

Summary.

The Committee recommends for adoption as a standard and printing in the MANUAL the Iodine-Potassium Ferricyanide-Starch Test for determining zinc chloride penetration as given on page 22.

The Committee further recommends the revision of the Standard Ferrocyanide Method of Analysis as indicated on page 7.

With the above exceptions the material in the report is presented as information.

Future Work.

For future work the Committee recommends that accumulation of data on actual experience with the joint committee method for sampling cars of oil for water be completed, and if the experience is favorable that the method be proposed for adoption as a standard.

It is further recommended that information on vertical-retort tar continue to be compiled.

Alfred L. Kammerer, *Chairman*
Ernest Bateman
F. G. Breyer
S. R. Church
L. S. Drefahl
W. H. Fulweiler
J. H. Gibboney
F. W. Kroemer
K. M. Waddell
Galen Wood

RESULTS OF SOME TESTS OF THE EFFECT OF ZINC CHLORIDE ON THE STRENGTH OF WOOD.*

By T. R. C. Wilson and Ernest Bateman.

About 6 years ago a small series of tests were undertaken at the Forest Products Laboratory as a study of the effect of zinc chloride on the strength of timber. The tests were planned to include Douglas fir and longleaf pine. Because of some difficulties in securing material, shortleaf pine was to a large extent substituted for longleaf. A small amount of spruce pine (*Pinus glabra*) was used to fill out the series.

Material for treatment and test was prepared in the form of air-dried sticks 2 inches by 2 inches by 8 feet. Each of these sticks was cut into a pair of pieces 4 ft. long, one of which was treated as described later, the other was left in an untreated condition and tested at the same time as the treated stick to which it was paired.

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*This paper was prepared by T. R. C. Wilson, Engineer in Forest Products, and Ernest Bateman, Chemist in Forest Products, as Exhibit "C" for the report of Committee No. 4—Preservatives.

Previous to treatment the sticks were divided into groups according to species and according to whether they were heartwood or sapwood. Each of these groups was then divided into 4 sub-groups, into one of which it was planned to inject 0.25 lb. dry zinc chloride per cubic foot, another sub-group 0.50 lb., another 0.75 lb., and another 1.00 pound. In order to accomplish this the strength of the solution was varied for the different sub-groups. This variation in strength of the solution was from 0.6% to 3.6%. The moisture content of the sticks previous to treatment averaged from 11% to 18% in the various sub-groups. Actual average absorptions from 0.22 lb. to 1.11 lbs. of dry salt were obtained.[1]

One-third of the sticks of each sub-group, together with the untreated sticks to which they were paired, were subjected to mechanical tests 4 months after treatment, one-third 1 year after treatment, and the remaining one-third 5 years subsequent to treatment. During the time between treatment and test the treated sticks with their corresponding untreated mates were stored in open sheds.

One-half the sticks from each period of seasoning from each sub-group were tested in static bending, and one-half in impact bending. Specimens for compression-parallel-to-grain tests were taken from each stick. Hardness, compression-perpendicular-to-grain and tension-perpendicular-to-grain tests were also made. These tests were all carried out in accordance with standard Forest Service methods.

Results.

The results are shown in charts Figs. 1 to 11. In these charts the ratio of the strength value of each treated stick to the same strength value of the untreated stick to which it was paired is plotted as a percentage. These ratios are plotted vertically, and the absorption of dry salt per cubic foot is plotted horizontally. In other words, vertical distance represents the ratio of the strength values of the treated stick to the corresponding untreated stick, and distance from the left-hand edge of the diagram the amount of dry salt per cubic foot absorbed by the treated stick.

As will be noted from an inspection of these charts the data secured are somewhat erratic. Figs. 1 to 6, inclusive, agree in indicating that for a short time following treatment (see diagrams for tests made 4 months after treatment) there is a relation between the amount of preservative absorbed and the strength properties of the wood. As the trend of the points indicates a decrease of strength properties with an increase in the amount of preservative absorbed, and as only a few of the points go above the 100% line, the conclusion is that the treated material is in general somewhat weaker than the untreated.

---

[1] A large variation in the absorption of different sticks of the same species treated in the same charge (and consequently subjected to exactly the same conditions of pressure, temperature, time and concentration of solution) was found.

In Figs. 1 and 4 (modulus of elasticity in static bending and maximum crushing strength in compression-parallel-to-grain) the points representing tests 1 year and tests 5 years after treatment indicate no relation between strength values and amount of preservative absorbed, and since almost one-half the points are above the 100% line it is indicated that treated material is very little, if any, weaker in these properties than the untreated. It may be said that there is apparently a very slight downward trend as the amount of preservative increases, but the very perceptible effect indicated by the tests 4 months after treatment has practically disappeared.

The corresponding points in Fig. 2 (modulus of rupture) may be said to have a similar slight downward trend with increased amounts of preservative; moreover, quite a large proportion of the points fall below the 100% lines, indicating that the weakening effect had not entirely disappeared.

Fig. 3 (fiber stress at elastic limit in static bending) indicates that at the 4 months and 5 years periods there is in general a downward trend to strength values as absorption of preservative increases. This tendency is scarcely apparent at 1 year. The fact that a considerable majority of the points are below the 100% lines is a strong indication of weakening in this property.

In Figs. 7 to 11 (tension-perpendicular-to-grain, hardness, and compression-perpendicular-to-grain) it is impossible to trace any relation between strength values and amount of dry salt absorbed.

CONCLUSIONS.

The data shown are, as has been pointed out, somewhat erratic and lacking in consistency. It is believed, however, that taken in conjunction with the other data which are discussed and referred to by the Committee on Preservatives they justify the statement of the following tentative conclusions:

That for a short time subsequent to treatment there is a relation between concentration of preservative (in the wood) and strength properties, but that later changes take place which modify this relation.

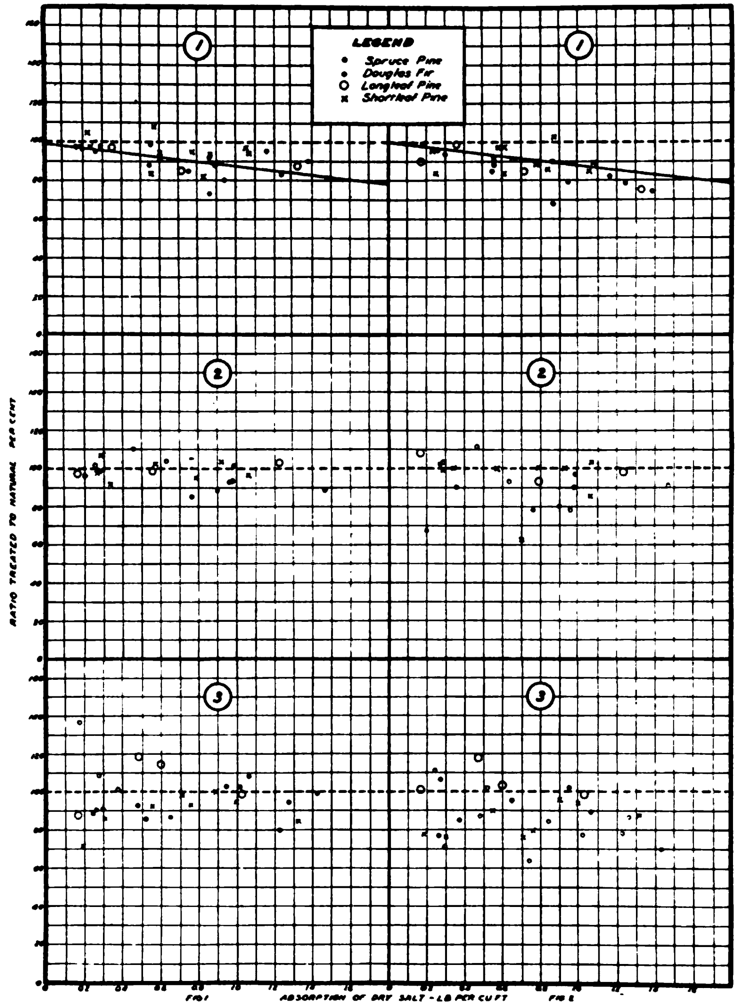
With some properties, such as modulus of elasticity and maximum crushing strength, the effect of the preservative very largely disappears. In other cases, such as those test values which are indicative of resistance to shock (work to maximum load in static bending and height of drop in impact bending) the effect of the lighter concentrations increases and there is a fairly definite indication of permanent and possibly increasing deteriorating effect.

The data are insufficient to yield information as to whether treatment with zinc chloride differently affects different species.

Attention is called to the fact that the sticks used in these tests were small (2 inches by 2 inches by 4 feet), and quite thorough penetration of the solution was secured, so that the salt was quite uniformly distributed through the stick.

If in the commercial treatment of ties or larger timbers an average absorption of a certain amount of dry salt, say ½ lb. per cubic foot, is obtained this absorption will be much greater than the average in some timbers and much less in others. Particularly is it to be expected that the outer parts of large timbers will receive much more than the average amount of salt, while the central portions may get little, if any.

Consequently, while commercial treatments are supposed to inject an average of ½ lb. of dry salt per cubic foot it is probable that the outer portions will receive a much greater concentration.



MODULUS OF ELASTICITY
IN
STATIC BENDING

MODULUS OF RUPTURE
IN
STATIC BENDING

NOTE 1.- Tested four months after treatment.
2. " one year " "
3 " five years " "

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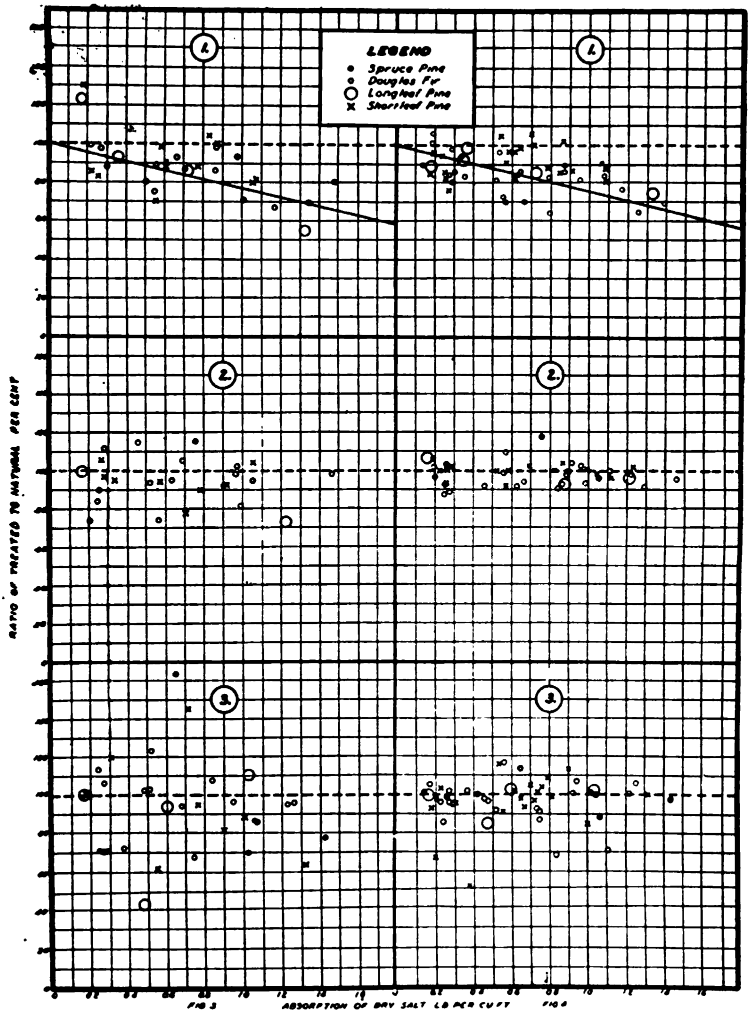

FIBRE STRESS AT ELASTIC LIMIT
IN
STATIC BENDING

MAXIMUM CRUSHING STRENGTH
IN
COMPRESSION PARALLEL TO GRAIN

NOTE: 1 Tested four months after treatment
2 - one year
3 - five years

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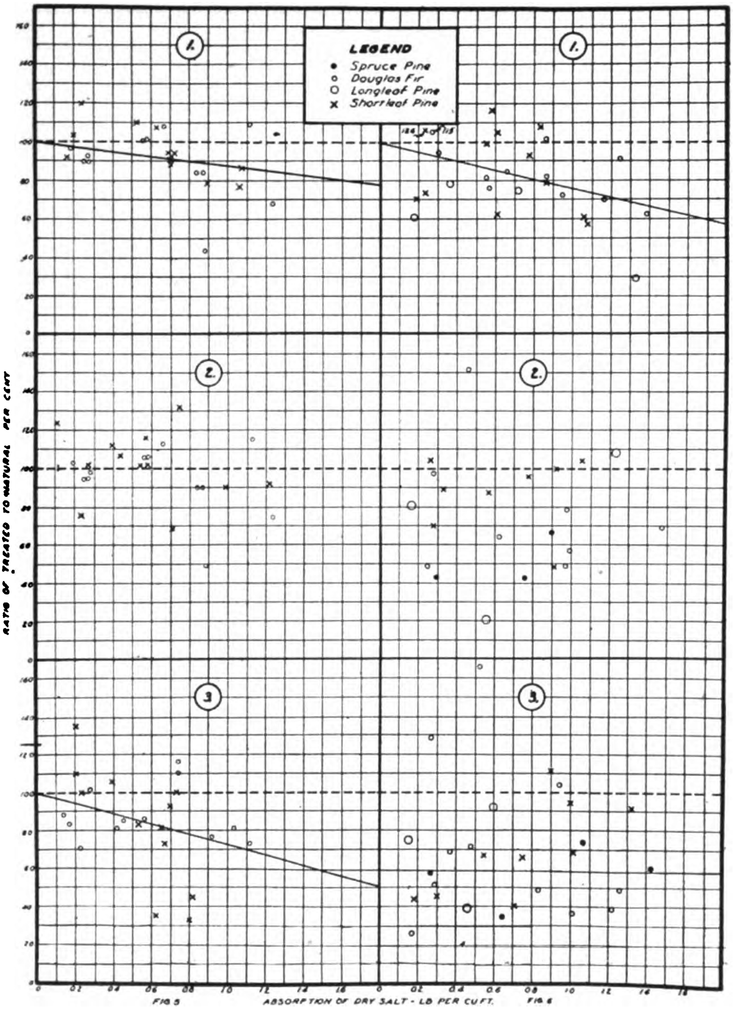

FIG 5

HEIGHT OF DROP
IN
IMPACT BENDING

FIG 6

WORK TO MAXIMUM LOAD
IN
STATIC BENDING

NOTE
1 - Tested four months after treatment
2 " one year " "
3 " five years " "

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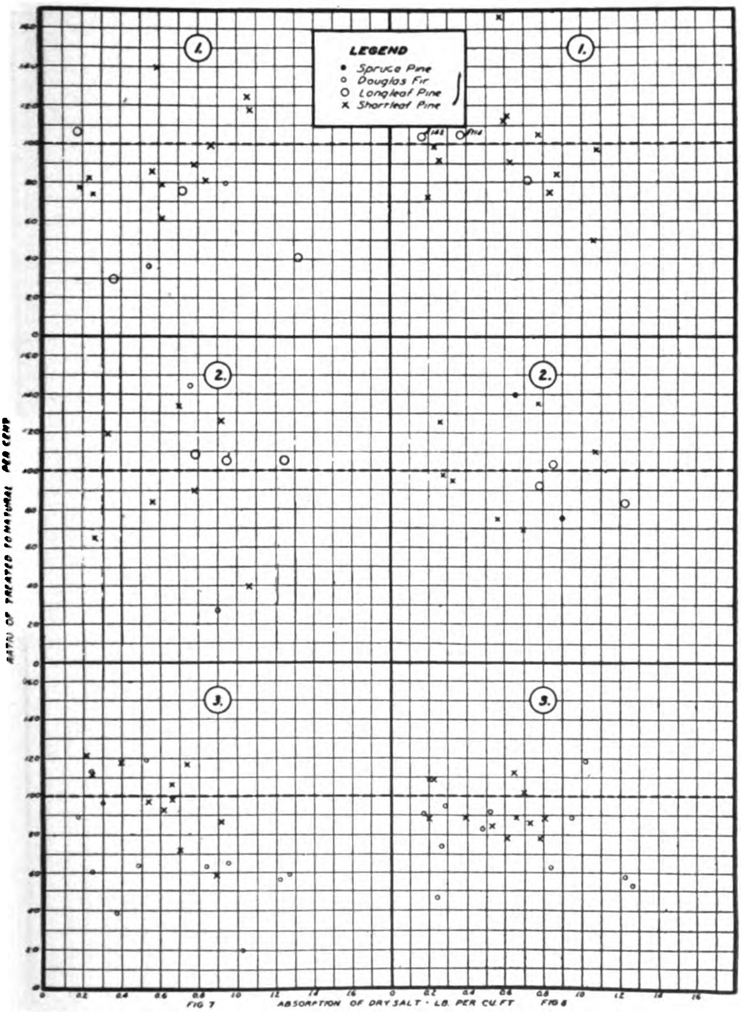

TENSION PERPENDICULAR TO GRAIN-TANGENTIAL

TENSION PERPENDICULAR GRAIN-RADIAL

NOTE: 1. Tested four months after treatment
2. " one year " "
3. " five years " "

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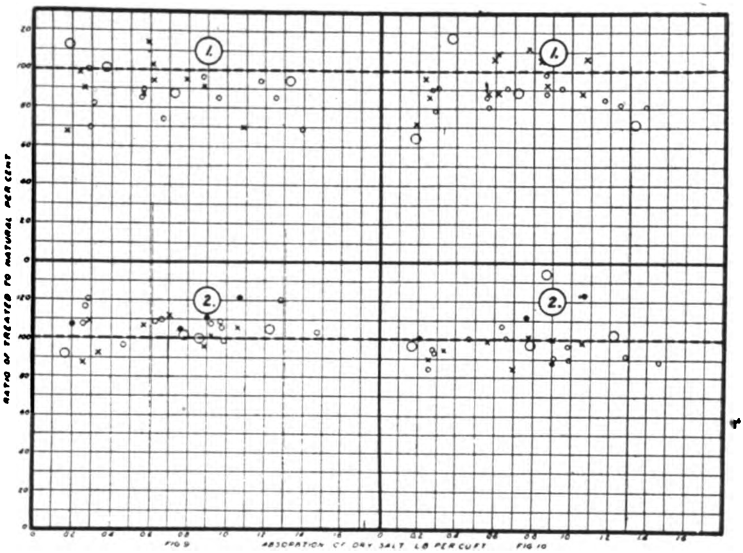

FIG 9 FIG 10

END HARDNESS SIDE HARDNESS

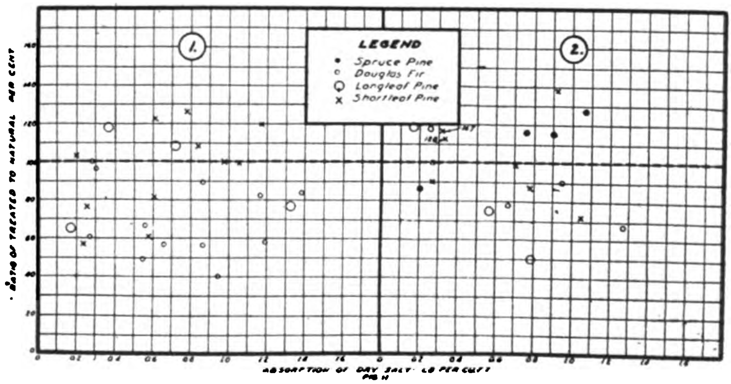

FIG 11

FIBRE STRESS AT ELASTIC LIMIT
IN
COMPRESSION PERPENDICULAR TO GRAIN

NOTE 1 Tested four months after treatment
2 " one year "

[illegible]

THE EFFECT OF THE ZINC CHLORIDE PROCESS OF PRESERVATION ON THE STRENGTH OF STRUCTURAL TIMBER.*

By H. B. Luther,

Assistant Professor of Civil Engineering, Massachusetts Institute of Technology.

Foreword.

It is well known that various chemical preservatives with which timber is treated to prevent rot have an effect on some of the physical properties of the timber. As the need of a preservative is in large part due to the high cost of replacing timbers after they have deteriorated, the prevention of rot at the cost of a certain amount of strength is of undoubted value, but it is important to know under what conditions the reduction of strength due to a given preservative may be too rapid or too marked to make its use feasible. The study of this problem of the proper limiting conditions for the use of the Burnett, or zinc chloride process has been the object of the investigations reported herein. The work was undertaken in the Department of Civil Engineering at the Massachusetts Institute of Technology as the result of a suggestion made by Mr. F. J. Hoxie, Engineer for the Associated Factory Mutual Fire Insurance Companies, who, in a letter of April 1, 1914, to Prof. C. M. Spofford, stated:

> "It is desirable to know just what effect chloride of zinc as commonly used for timber preservation has on the strength of wood."

The investigations were carried out during 1915 to 1918 as thesis work in the senior year by the following Technology students:†

Alfred H. Clarke, - - - -	Class of 1915.
Thomas W. Little, - - - -	" " 1916.
Herman L. Rogers, - - - -	" " 1917.
Albert Haertlein, - - - -	" " 1918.

These tests were confined to specimens of loblolly sapwood of 2 ins. x 2 ins. x 30 ins. size and the treatment, while in commercial quantity, was made by immersion in a cold solution and in no case by the pressure process, so that some further studies may well be deemed feasible. On the other hand, the tests were ably conducted, the effect of time and temperature were studied and certain important conclusions seem definitely established so that it is highly desirable to present a resume' of these tests for the benefit of those interested in the use of this wood preservative and as a valuable contribution toward the subject in connection with such further studies as other investigators may undertake.

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*This paper was submitted as a part (Exhibit B) of the Report of Committee No. 4—Preservatives.

†These men worked under the supervision of Prof. J. M. Barker, who took a great interest in the work and was largely responsible for the manner in which the experiments were carried out.

Summary.

The problem was considered to be concerned chiefly with the physical changes in the treated timber in rooms at varying temperatures and after some length of time. For this reason specimens were chosen in 2 series-blanks, or untreated test specimens, and impregnated test specimens, there being a blank for each treated specimen, taken from the same original stick. Each specimen was marked with an identification mark to indicate what stick it came from and what treatment was given. The specimens were stored in a group in the corner of the laboratory at room temperature and in ovens which were kept continuously at 100° F. and 150° F., respectively, and a record of the humidity in these storage rooms was kept.

At periods varying from 3 months to 2 years, groups of from 6 to 10 specimens of both the blanks and treated pieces were tested in direct compression and in cross-bending to determine the difference in the strength of the treated and untreated specimens.

In all, 118 specimens were tested, grouped as follows:

Number of Specimens.	Length of Time Stored.	Temperature of Storage Room. (Fahrenheit.)	Humidity of Storage Room.
10 Treated	1 year	Room Temp. (75° +)	
9 Untreated	1 "	" "	
10 Treated	2 years	" "	
10 Untreated	2 "	" "	
7 Treated	1 year	100°	30%
7 Untreated	1 "	100	30
9 Untreated	2 years	100	30
9 Untreated	2 "	100	30
10 Treated	3 months	150	11
10 Untreated	3 "	150	11
11 Treated	1 year	150	11
10 Untreated	1 "	150	11
3 Treated	2 years	150	11
3 Untreated	2 "	150	11

The results of these tests, as indicated in plots, are summarized thus:

(1) For the specimens stored at 75°F.:

No appreciable difference in strength between the treated and untreated timbers.

(2) For those stored at 100° F.:

In compression parallel to the grain, a decrease 3.5% in treated specimens; in cross-bending, a decrease of 17.6%.

(3) For those stored at 150° F.:

In compression parallel to the grain, a decrease of 20.6% in the treated specimens; in cross-bending, a decrease of 49%.

CONCLUSIONS.—These results lead to the following conclusions:

(1) Zinc chloride, when used as a preservative, decreases the strength of timbers subjected to relatively high temperatures. The deteriorating effect is likely to be very marked when extreme conditions of heat are encountered. Furthermore, the deterioration is continuous, for several years, at least.

(2) There is a safe temperature below which the effect of the zinc chloride is negligible. This limiting temperature cannot be definitely fixed from the information now at hand, but is somewhat higher than 75° F., although the deteriorating effect is marked when the temperature is 100° F.

A description of the methods and apparatus employed, and a complete resume' of the tests are given in order that the validity of the conclusions may be studied and important information not properly digested in this paper may still be available to its readers.

Choice of Specimens and Method of Marking Them.

Sapwood is that first attacked by fungus growths, and hence first in the need of preservative treatment. Also sapwood is much more absorptive than heartwood, and takes up the treating fluid more easily. For this reason a choice was made of North Carolina pine, a loblolly which was easily obtained in pieces entirely of sapwood and clear of defects. A size of 2 ins. x 2 ins. x 30 ins. was chosen as convenient for the specimens and, in general, the plan was to use 6 to 10 of these specimens, carefully prepared, for any one type of test.

Specimens Nos. 1 to 3 were prepared by Mr. Clarke, in March, 1915, and Nos. 4 to 10 by Mr. Little, in November, 1915. [Mr. Clarke reports that his timber was purchased from the Wyman-Allen Lumber Company, of Charlestown, and in size the pieces were originally: 2 2 ins. x 8½ ins. x 16 ft.; 3 2 ins. x 8 ins. x 16 ft. One face of stick No. 2 was nearly all heartwood, but the other two sticks were entirely sapwood and in all cases were free from defects.]

Test specimens 2 ins. x 2 ins. x 30 ins. were cut from the sticks and were numbered with the number of the stick and an individual specimen number and were marked "a," "b" or "c," according to whether they were used for an original absorption test, were left untreated, or were treated with the zinc chloride solution. Later the specimens were marked with a subscript 1, when stored at 150° F.; 2, when stored at 100° F.; or 3, when stored at room temperature. Thus a test-piece marked 5–9–c_3 was the ninth test-piece of timber No. 5, was impregnated and was stored at room temperature.

Study of Effect of Concentrated Solution.

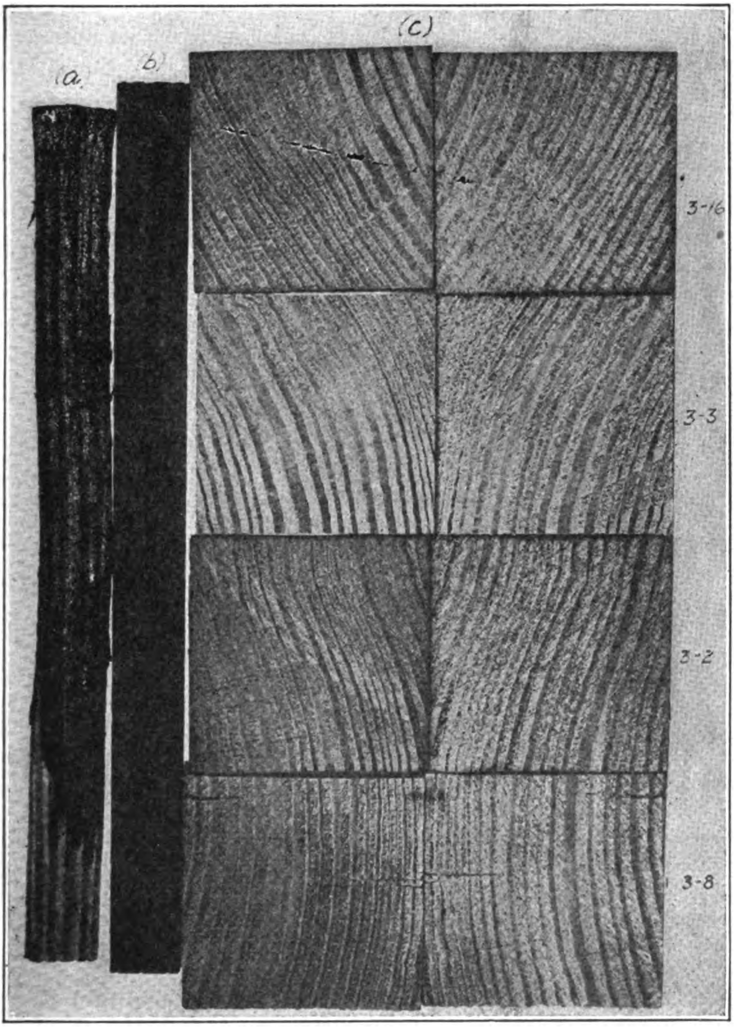
In order to determine how seriously a strong solution of zinc chloride might affect wood, a couple of specimens of loblolly sapwood, ¼ in. x ½ in. in cross-section and 7½ ins. long, were placed upright in a strong solution of zinc chloride and kept at 150° F. for a week. They stood on one end in about 3 inches of the solution in an open-glass jar. About the top of the jar a paper was tied loosely, and the sticks protruded through it. After having been kept at 150° F. for a couple of days, it was noticed the wood had drawn the solution up above the top of the jar, and that ½ inch above the paper covering there was a discoloration progressing. Gradually the fiber of the wood was destroyed at this point, and two days later the sticks had no strength and were bending under their own weight.

The water, of course, evaporated from the solution, but the jar was twice refilled. The disintegration of the wood continued, and it became as black as charcoal just above the paper covering of the jar. At the end of a week, all the water meanwhile having evaporated, the sticks were found to have turned entirely black throughout their length, and had a decided charcoal appearance when dry. The wood was brittle and showed every evidence of a partial oxidation. This test was extreme as no such concentrated solution is used commercially, but it is of interest as indicating the chemical activity of the zinc chloride on timber.

Method of Impregnation of the Treated Specimens.

In commercial plants the timber is impregnated either by pressure in closed retorts, or by dipping in hot liquid in an open tank. In either case the timber is first steamed to drive out moisture, which in the second stage of the process is supplanted by the zinc chloride solution.

In order to eliminate any possibility of injury to the wood by heat in connection with the treatment for this study, it was decided to impregnate the test-specimens by immersion in cold liquid at atmospheric pressure.



Showing (full size)

(a) Small specimen attacked by strong solution of zinc chloride at 150° F. in 1 week's time.

(b) Small specimen impregnated with 20% solution zinc chloride and subjected to 150° F. for 1 week.

(c) Sections of typical specimens. Nos. 3–2 and 3–16 have been treated with zinc chloride 4% solution. Nos. 3–3 and 3–8 being blanks. All stored at 150° F. for 40 days.

(Notice penetration of discoloration around edges of treated specimens.)

The sapwood specimens proved very satisfactory as they absorbed the desired amount of the salt (by weight) within a reasonable time, without necessitating the use of so strong a solution as to be dangerous.

The amount of zinc chloride commonly used is ½ lb. dry to a cubic foot of timber, and care was taken throughout these studies to obtain this same amount of impregnation. Commercially, a 1.5% to 2% solution is used, but in the preparation of these test-specimens a 4% cold bath was employed.

Before the treatment of the regular test-specimens some random specimens were selected and subjected to an absorption test in order to determine the proper treatment to obtain the ½ lb. per cubic foot. The data from these tests are given elsewhere.

The volume of a 2 in. x 2 in. x 30 in. piece is 0.07 cu. ft. Eight ounces of salt per cubic foot is desired.

$\frac{8 \times .07}{.04}=14$; therefore 14 ozs. of 4% solution is needed to give the proper impregnation in one of these specimens. In general, about 5 days' immersion was necessary for this.

Storage and Storage Apparatus.

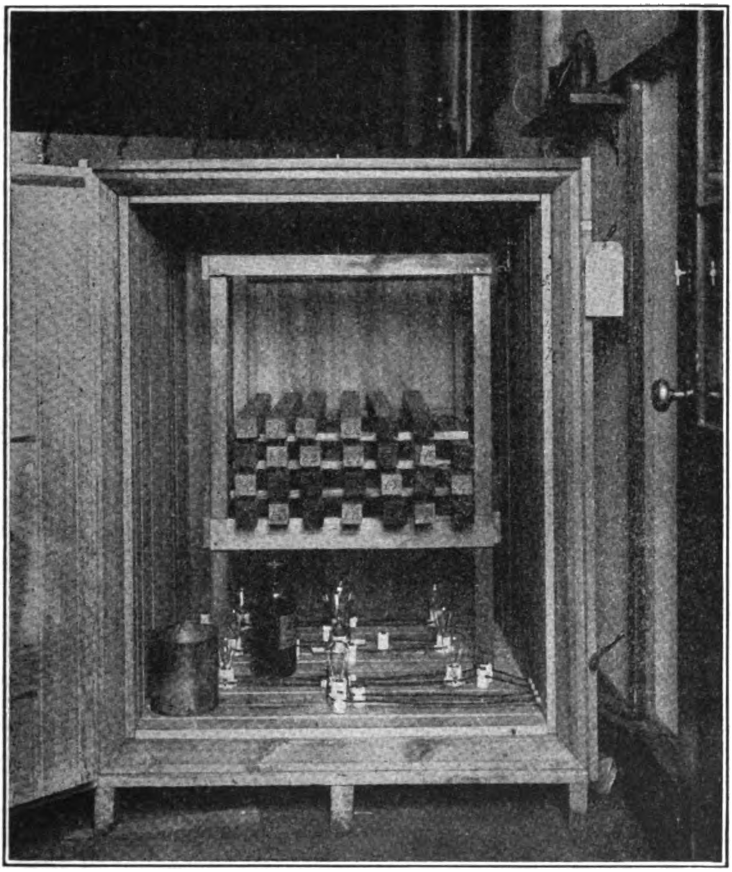
It was assumed that in ordinary factory buildings, where timber treated with zinc chloride would be most commonly used, the range of temperature is not very great, presumably from 60° F. to 100° F., with a higher temperature near steam-pipes and boilers. The specimens were, therefore, stored at room temperature in the laboratory at the Massachusetts Institute of Technology, which gave an average temperature of 75° F., and in ovens, one of which was kept at 100° F., and the other at 150° F.

The humidity in the oven at 150° F. averaged about 11%; in the oven at 100° F. it averaged 30%, and in the part of the laboratory where the specimens were stored in the open, it averaged about 42%.

The ovens used for storage were constructed for this particular work. and are described in the following paragraphs:

OVEN NO. 1.—The oven which was used for storage at 150° F. is a double-walled, rectangular box, 3 ft. x 3 ft.-6 ins. x 3 ft.-10 ins., inside measurement. The top, bottom and walls are of ⅞ in. matched flooring, and built of 2 layers, separated by a 2-in. space filled with saw-dust. A door, the full size of one end, admits the placing and removal of specimens which are stacked on a framework allowing 12 ins. clear space beneath the pile of specimens and 6 ins. around and over the top.

Heat is supplied by electric lamps in 9 sockets in the floor, so spaced as to be in the center of equal areas of floor space. Two circuits are provided, 1 leading direct from the mains supplies heat at all times, the other runs from the mains through a relay switch, actuated by a battery circuit controlled by a thermostat. In the relay circuit are 4 lamps; in the other, the remaining 5. By this division of the current it is possible to provide power enough by the main circuit to overcome losses by radiation for the normal number of degrees difference between room and cabinet temperatures, and in case of fluctuation below the normal room



Oven No. 1.

temperature, the thermostat is arranged to turn on additional power. It was found that the heat lost by radiation is about 4.5 B. t. u. per square foot of area per 24 hours per degree difference in temperature.

The thermostat used consists merely of a gutta-percha-brass thermometer with proper electrical contacts. The relay is an ordinary telegraphic relay remodelled to provide greater breaking distance and contact area by the lengthening out of the moving arm and the fixture thereon of carbon poles. It is enclosed in a fireproof asbestos box, and is operated by current from the lighting circuit protected by the resistance of 2 30-watt lamps in series.

No attempt was made to control the humidity in this oven, but a jar of open water was kept constantly in it while specimens were stored and measurements indicated a practically constant condition of 10% to 12% relative humidity.

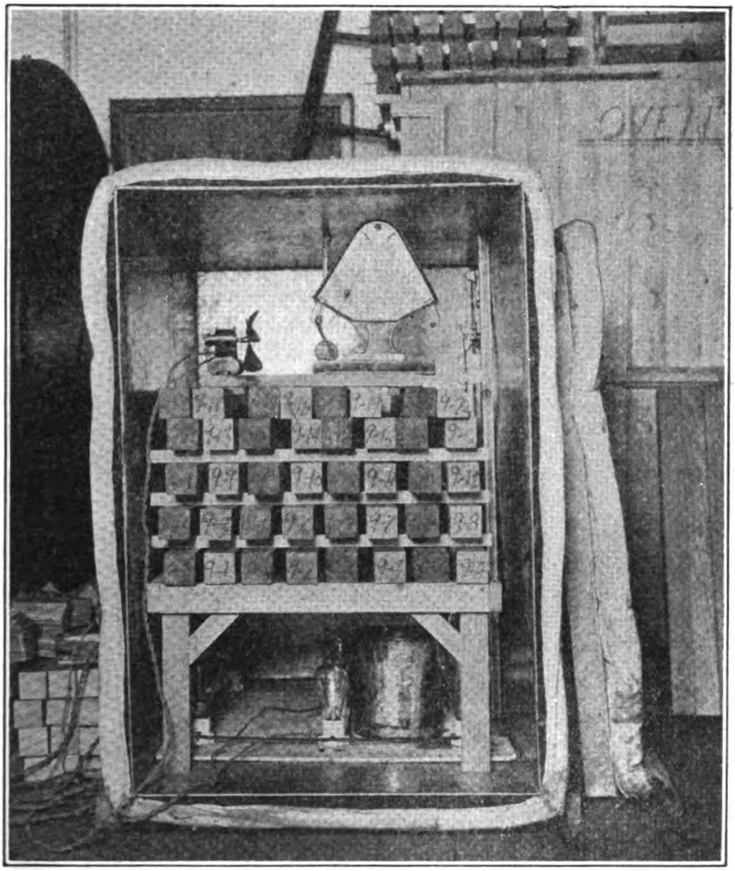
OVEN NO. 2.—This oven was constructed in 1915 and used for storing specimens at a constant temperature of 100° F. The relative humidity within this oven remained practically constant at about 30%.

This oven is a stiff, iron box, 3 ft. high, 3 ft. deep and 2 ft. wide. One of the ends is detachable, being held in place by a tight-fitting flange which fits inside the end of the oven, and serves as a door. The oven and door are insulated against heat by a 2-in. layer of hair-felt, the whole being kept in place by a neat exterior covering of canvas. The interior surface of the oven is the sheet iron itself. The capacity is about 65 2 in. x 2 in. x 30 in. specimens, which are supported by a wooden frame which allows about a foot of clear space below the pile of sticks.

Heat is supplied by means of 4 100-watt electric lamps in sockets near the corners of the floor. Normally these lamps are connected in series giving a total of about 25 watts. If for any reason the temperature in the oven falls below 100° F., the thermostat, mounted upon the wall, closes a connection which short-circuits the current through only 1 of the lamps, this giving the heat equivalent of 100 watts. This causes a rise in the oven temperature, and when 100° F. is again reached, the thermostat opens and thereby throws all 4 lamps in service again, cutting down the power to 25 watts.

The thermostat in oven No. 2 consists merely of an ordinary gutta-percha-brass thermometer with proper electrical contacts.

The humidity was maintained constant by keeping a jar filled with water in the oven and measurements indicated about 30% relative humidity.



Oven No. 2.

Physical Tests and Apparatus Used.

The physical tests made upon the specimens were 3 in number, and covered the following determinations:

(1) The strength in cross-bending as measured by the modulus of rupture.

(2) The strength in compression parallel to the grain, as measured by the breaking load in pounds per square inch.

(3) The moisture content, measured as a percentage of the dry weight of the specimen.

The results of the first 2 tests were reduced to a common moisture content, the correction being applied only to the average result from a set of specimens.

The cross-bending tests were made upon a "cast-iron arbitration bar" machine. The end supports were set 28 ins. apart, and the load was applied at the center at the rate of 500 lbs. per minute.

The tests in compression parallel to the grain were made upon pieces 4 ins. in length, cut from the uninjured portions of the sticks which had been broken in bending. In sawing these blocks great care was taken to have the ends square and parallel. These pieces were then compressed to destruction, parallel to the grain, in a 100,000-lb. Olsen testing machine; the slowest speed of the machine was used in loading, the application of the load being at the rate of about 15,000 lbs. per minute.

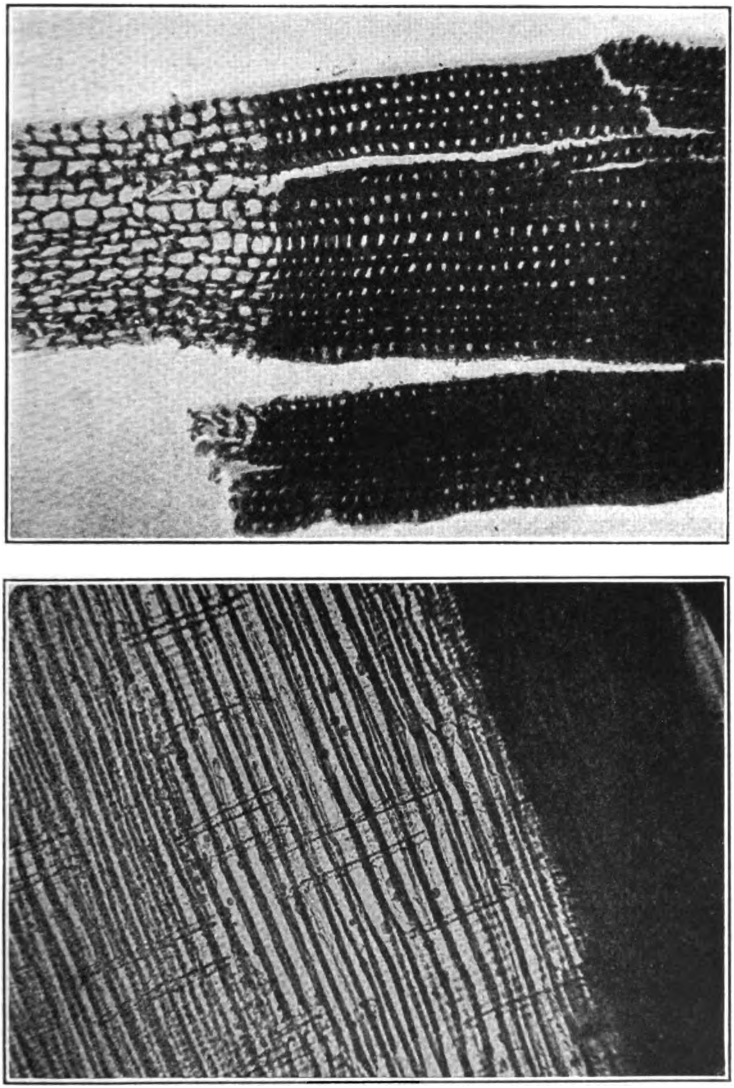
After breaking each specimen in cross-bending, a section about ½ in. thick was cut as near the section of failure as possible, and weighed. These sections were then heated to 212° F. at atmospheric pressure, till a constant weight was reached. The moisture content was then figured as a percentage of the dry weight.

Microscopic Studies.

In 1916 Mr. Little made certain microscopic studies, which, while they have never furnished any definite conclusions, may be of interest to those versed in microscopy; therefore, the microphotographs are printed, and his description of the work given herewith:

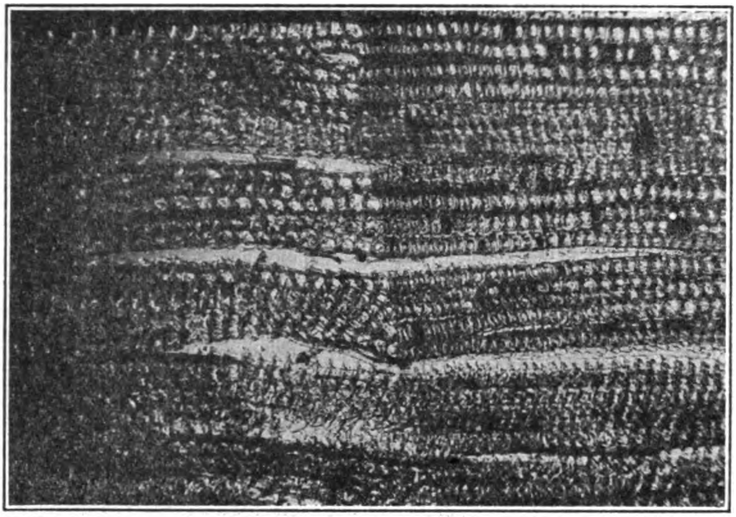
> The specimens were small pieces about ⅛ in. by ½ in. by 1 in. cut with a jack-knife from the standard specimen. These were taken from 6 sticks in oven No. 1 (Nos. 2–19, 2–18, 1–4, 1–3, 7–10, 8–10), 2 in oven No. 2 (6–20, 9–20) and 2 from the small piece which Mr. Clarke treated with 20% solution zinc chloride and stored in oven No. 1 (known herein as A–20%). This selection gave a representative set of samples. From these samples, 31 slides were prepared.
>
> The most successful slides were prepared as follows: The samples were first soaked in melted paraffin to soften them and furnish a supporting matrix about the fibers. Sections were then cut, both longitudinally and across the grain, by hand, with new Gillette razor blades.
>
> These sections could be cut extremely thin, without tearing, if proper care was used. The sections were then soaked for about 10 minutes in absolute alcohol to remove the water, and were then immersed for an equal period of time in xylene, to clear them. They were then mounted in the usual manner in a drop of Canada balsam on a glass slide, and covered with a standard cover-glass.
>
> The microphotographs were taken at night with a microscope fitted with a camera bellows and a 4 in. by 5 in. plate-holder. Transmitted light was used, supplied by a small electric arc, and made monochromatic by passage through a green glass filter. The exposure

was determined by trial, and varied from 30 seconds to 5 minutes. The microscope was used with an objective of 16 m.m. focal length, giving a magnification on the negative of about 75 diameters.

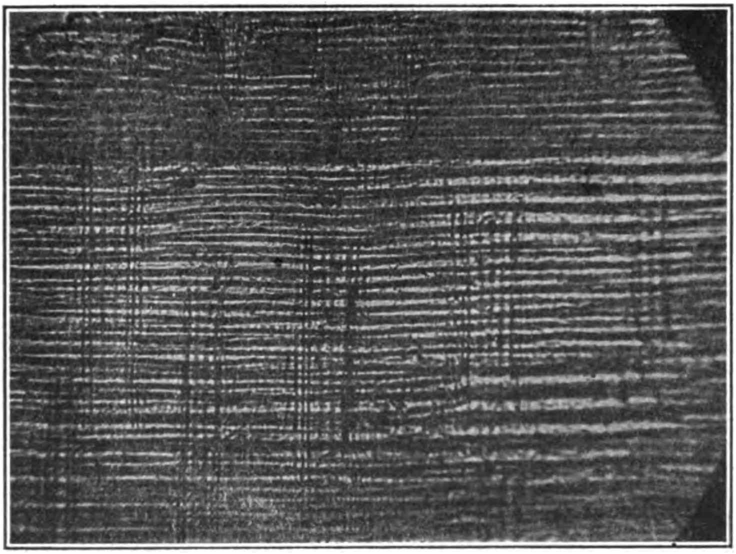


"A-20%"

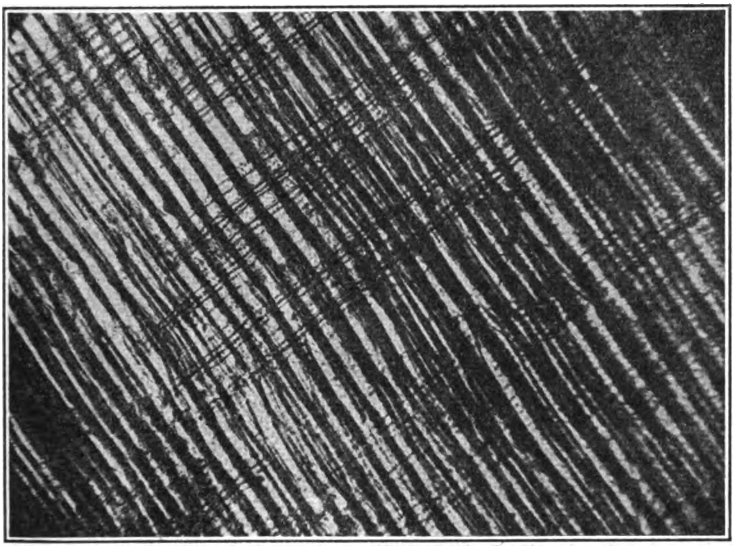
Small Specimens Treated with 20% Solution Zinc Chloride and Stored 1 Year at 150° F. and 11% R. H.



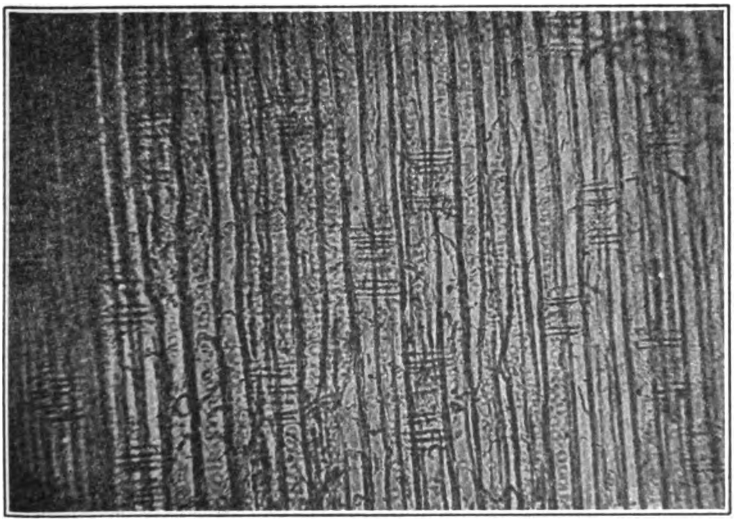
6-20-c-2
Treated, Stored 4 Months at 100° F. and 80% R. H.



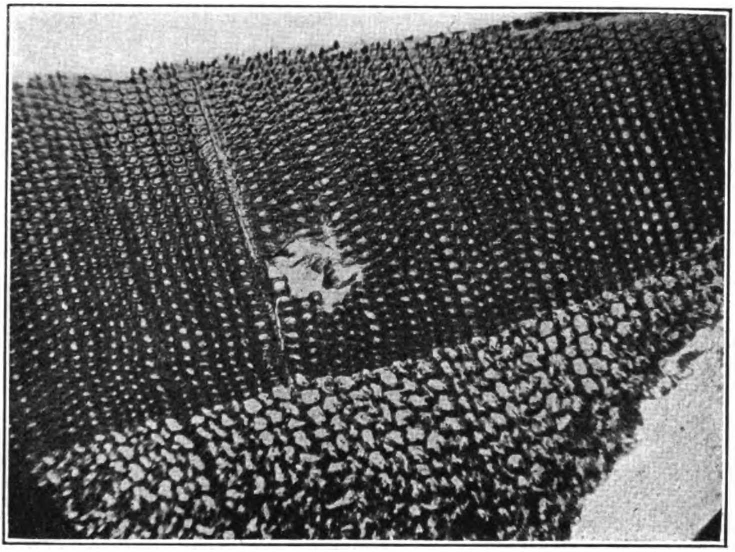
9-20-b-2
Untreated, Stored 4 Months at 100° F. and 80% R. H.



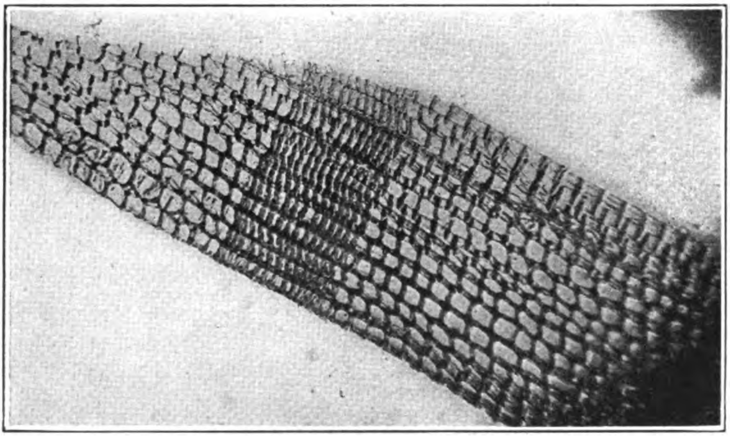
1-4-c.
Treated, Stored 1 Year at 150° F. and 11% R. H.



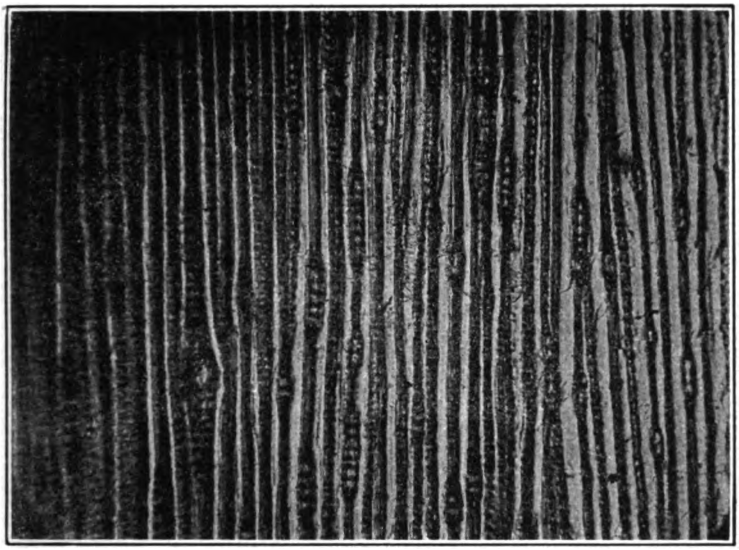
1-3-b.
Untreated, Stored 1 Year at 150° F. and 11% R. H.



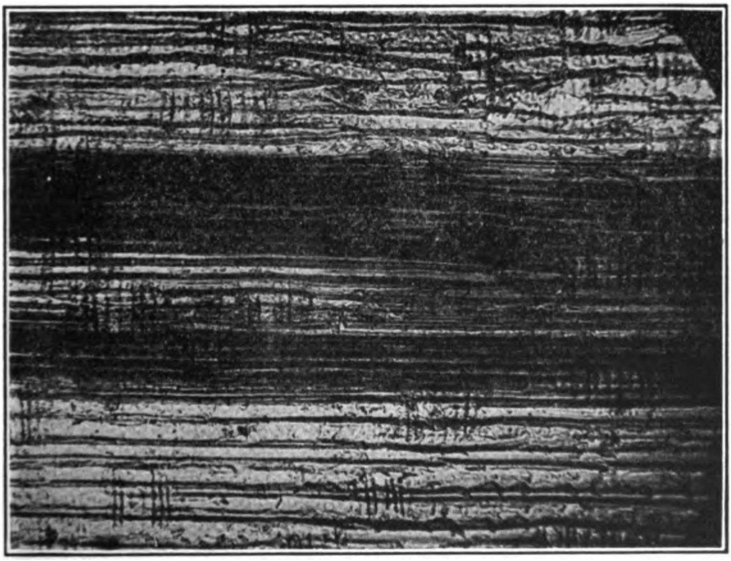
2-19-c,
Treated, Stored 1 Year at 150° F. and 11% R. H.



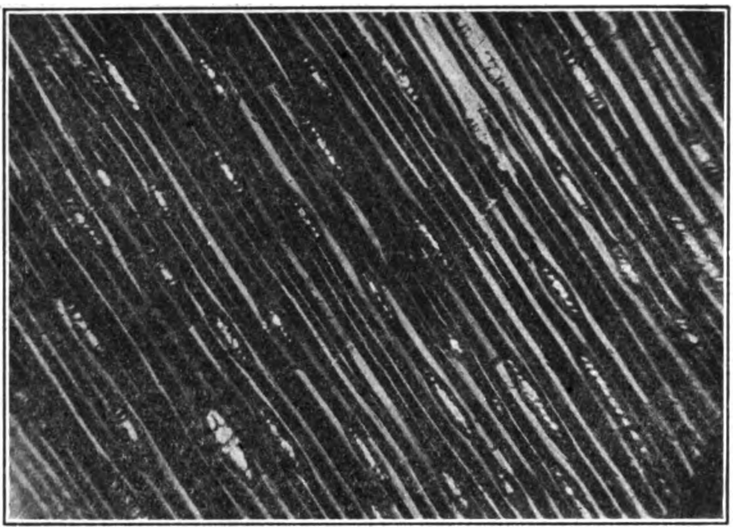
2-18-c,
Untreated, Stored 1 Year at 150° F. and 11% R. H.



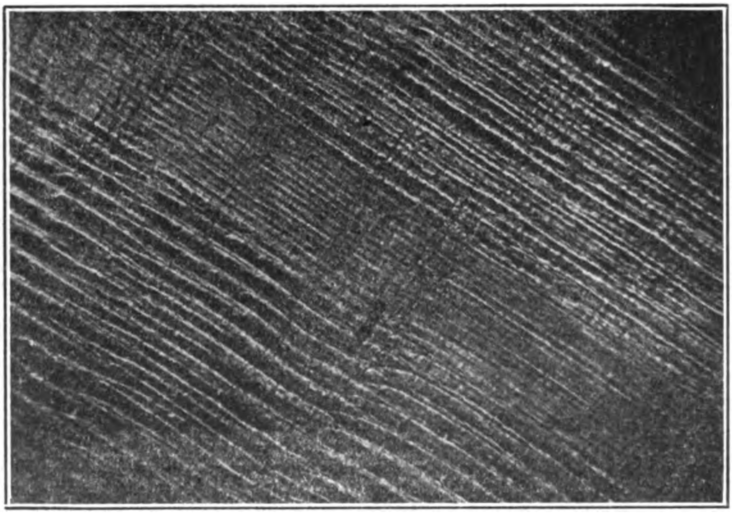
8-10-b,
Untreated, Stored 3 Months at 150° F. and 11% R. H.



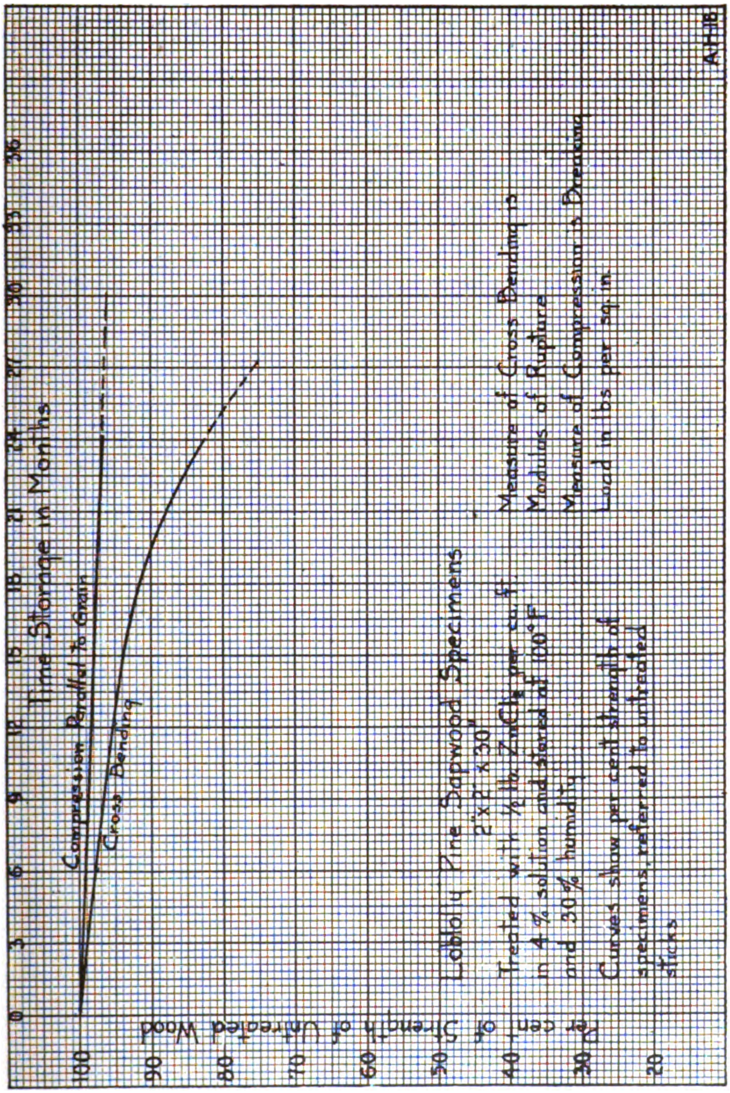
7-10-c,
Treated, Stored 3 Months at 150° F. and 11% R. H.

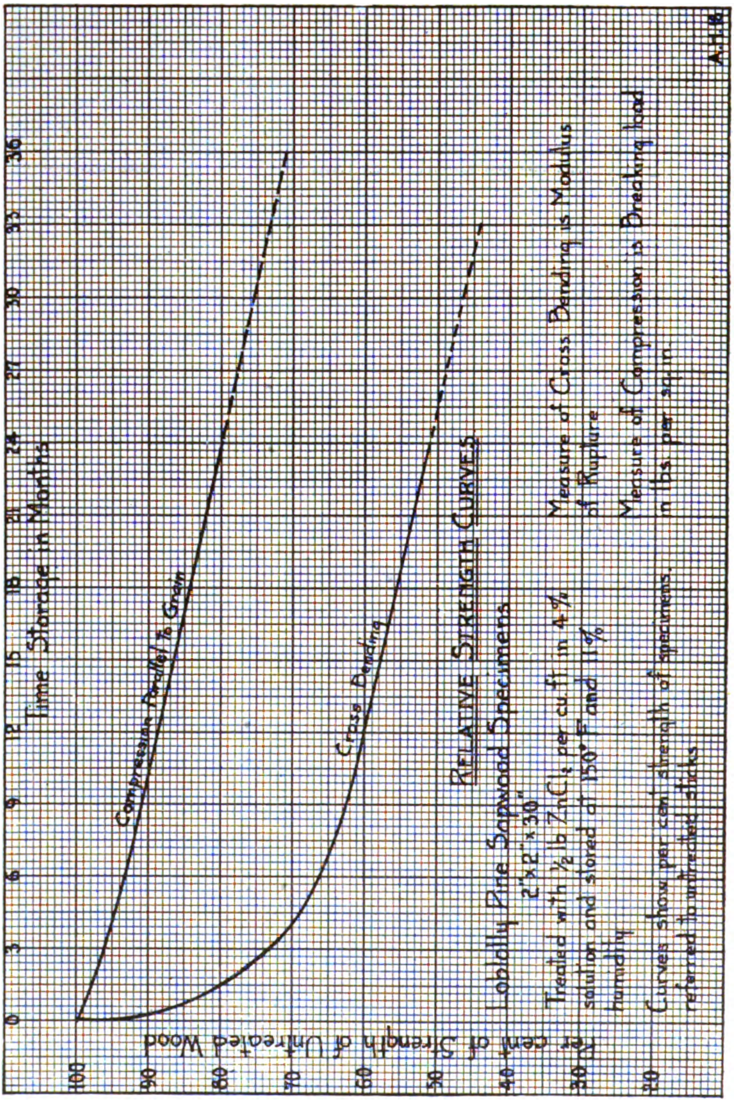


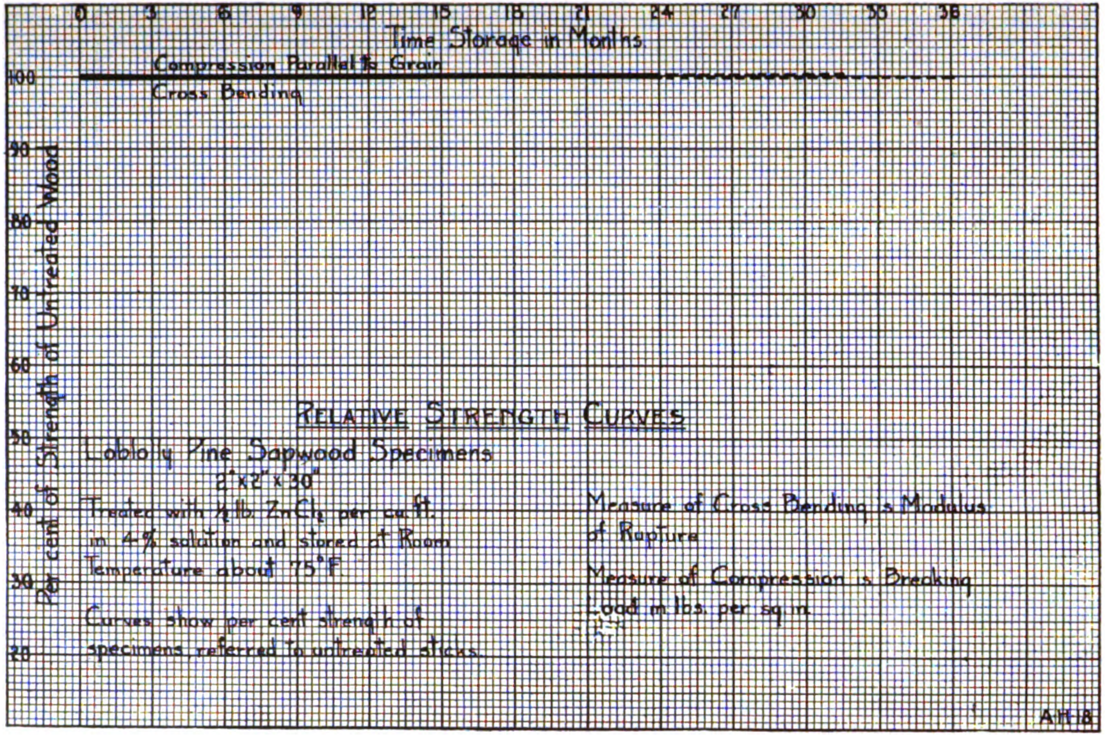
2-19-c.
Treated. Stored 1 Year at 150° F. and 11% R. H.



2-18-b.
Untreated, Stored 1 Year at 150° F. and 11% R. H.


Time Storage in Months
0
3
6
9
12
15
18
21
24
27
30
33
36
Per cent of Strength of Untreated Wood
100
90
80
70
60
50
40
30
20
Compression Parallel to Grain
Cross Bending
Loblolly Pine Sapwood Specimens
2"x2"x30"
Treated with ½ lb. ZnCl₂ per cu. ft.
in 4% solution and stored at 100°F
and 30% humidity
Curves show per cent strength of
specimens, referred to untreated
sticks
Measure of Cross Bending is
Modulus of Rupture
Measure of Compression is Breaking
Load in lbs per sq. in.
AH-18


Time Storage in Months
0
3
6
9
12
15
18
21
24
27
30
33
36
Per cent of Strength of Untreated Wood
100
90
80
70
60
50
40
30
20
Compression Parallel to Grain
Cross Bending
RELATIVE STRENGTH CURVES
Loblolly Pine Sapwood Specimens
2"×2"×30"
Treated with ½ lb ZnCl₂ per cu. ft. in 4% solution and stored at 150° F and 11% humidity
Curves show per cent strength of specimens referred to untreated sticks.
Measure of Cross Bending is Modulus of Rupture
Measure of Compression is Breaking load in lbs. per sq. in.
A.H.B.


0
3
6
9
12
15
18
21
24
27
30
33
36
Time Storage in Months
Compression Parallel to Grain
Cross Bending
100
90
80
70
60
50
40
30
20
Per cent of Strength of Untreated Wood
RELATIVE STRENGTH CURVES
Loblolly Pine Sapwood Specimens
2"x2"x30"
Treated with ½ lb. ZnCl2 per cu. ft.
in 4% solution and stored at Room
Temperature about 75°F
Curves show per cent strength of
specimens referred to untreated sticks.
Measure of Cross Bending is Modulus
of Rupture
Measure of Compression is Breaking
Load in lbs. per sq. in.
AH 18

DESCRIPTIONS OF INDIVIDUAL TESTS.—The following descriptions of the individual tests are presented substantially as reported by the students who carried out the tests themselves. The data are given in tabulated form in another section, but these descriptions give some detail about the appearance of the specimens, the manner of failure so far as could be observed, and any special information necessary concerning the working out of results.

Report on Tests of Specimens Stored at 76° F. for One Year.

PROCEDURE.—On March 24, 1917, 19 specimens were broken in cross-bending and in compression parallel to the grain, and their moisture content was determined. These specimens had been stored for 16 months at room temperature, about 76° F, and about 40% relative humidity.

RESULTS.—The average moisture content of the treated sticks was 7.9%; of the untreated sticks, 5.8%.

The average modulus of rupture of the blanks was 18.936 lbs. per square inch, while that of the treated sticks was 19,018 lbs. per square inch, or 0.43% greater.

The unit-breaking load, in compression parallel to the grain, was 10,529 lbs. per square inch for the blanks and 9,122 lbs. per square inch for the treated sticks, 13.3% less.

All specimens failed in tension, but the treated sticks were very brittle compared to the others, and showed a tendency to break suddenly and splinter badly.

The treated sticks were of somewhat darker color than the others.

Report on Tests of Specimens Stored at Room Temperature (about 76° F.) for Two Years.

PURPOSE AND PROCEDURE.—On March 20, 1918, 20 specimens were broken in bending and compression parallel to the grain, and their moisture content determined. These specimens had been stored at room temperature (about 76° F.) for a period of 2 years. Ten of these specimens had been treated with a 4% solution of zinc chloride at the rate of ½ lb. dry zinc chloride per cubic foot of wood.

RESULTS.—The average moisture content of the treated specimens was 5.61%; that of the untreated sticks, 3.71%. This difference made necessary the application of a correction factor in making comparisons of relative strength.

The strength of the treated specimens was 16.180 x 1.14=18,400 lbs. per square inch; that of the untreated, 18,360 lbs. per square inch in cross-bending.

The strength of the treated specimens in compression parallel to the grain was 11,900 lbs. per square inch; that of the untreated specimens was 11,980 per square inch.

CONCLUSIONS.—These results show that the treatment of timber with a 4% solution of zinc chloride at the rate of ½ lb. zinc chloride per cubic foot of wood has little or no effect on the strength of the wood neither in bending nor in compression parallel to the grain.

APPEARANCE OF SPECIMENS—One could not tell by eye which specimens had been treated and which had not.

Report on Tests of Specimens Stored at 100° F. for One Year.

PROCEDURE.—On April 17, 1917, 14 specimens were broken in cross-bending and in compression parallel to the grain, and their moisture content was determined. These specimens had been stored for a year at 100° F. and about 30% relative humidity. Seven of the specimens were treated and 7 were blanks.

RESULTS.—The average moisture content of the treated sticks was 5.1%; of the untreated sticks, 4.3%.

Average modulus of rupture of the blanks was 18,766 lbs. per square inch, while that of the treated sticks was 17,892 lbs. per square inch, or 4.7% less.

The unit-breaking load, in compression parallel to the grain, was 9,950 lbs. per square inch for the blanks, and 10,136 lbs. per square inch, or 1.8% more, for the treated sticks.

The untreated sticks all failed in tension. Four of the treated sticks failed in longitudinal shear, the failure of all 7 was more sudden and complete than that of the untreated sticks.

Both treated and untreated sticks retained the natural color of the wood, but the sections used for moisture determination showed a distinct darkening in the case of treated specimens after the moisture had been driven off at 212° F.

Report on Tests of Specimens Stored at 100°F. for Two Years.

PURPOSE AND PROCEDURE.—On April 8, 1918, 18 specimens were broken in bending and compression parallel to the grain, and their moisture content was determined. These specimens had been stored at 100° F. for 2 years at a relative humidity of about 30%. Nine of these specimens had been treated with a 4% solution of zinc chloride at the rate of ½ lb. dry zinc chloride per cubic foot of wood.

RESULTS.—The average moisture content of the treated specimens is 3.58%; that of the untreated sticks, 3.10%. This difference is large enough to make necessary a reduction of strength to the same moisture content. This reduction is applied to the averages and not to the individuals. It is made in accordance with the results obtained by Mr. H. D. Tieman of the U. S. Forest Service.*

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*H. D. Tieman, "Effect of Moisture Upon the Strength and Stiffness of Wood," Forest Service Bulletin No. 70, U. S Department of Agriculture.

The strength of the treated specimens in cross-bending was 14,400 lbs. per square inch. (corrected for moisture); that of the untreated was 17,500 lbs. per square inch. The strength of the treated specimens is 17.6% lower than the untreated in cross-bending.

The strength of the treated specimens in compression parallel to the grain was 12,650 lbs. per square inch; that of the untreated, 13,100 lbs. per square inch, the treated specimens being 3.5% less.

CONCLUSIONS.—The results show that the zinc chloride tends to reduce the strength of wood stored at 100° F. considerably in cross-bending and slightly in compression parallel to the grain.

APPEARANCE OF SPECIMENS.—The untreated specimens had practically the original color of the wood.

The treated specimens were discolored. The color is very dark brown. They are also much more brittle than the untreated specimens.

Report on Tests of Specimens Stored at 150° F. for 40 Days.

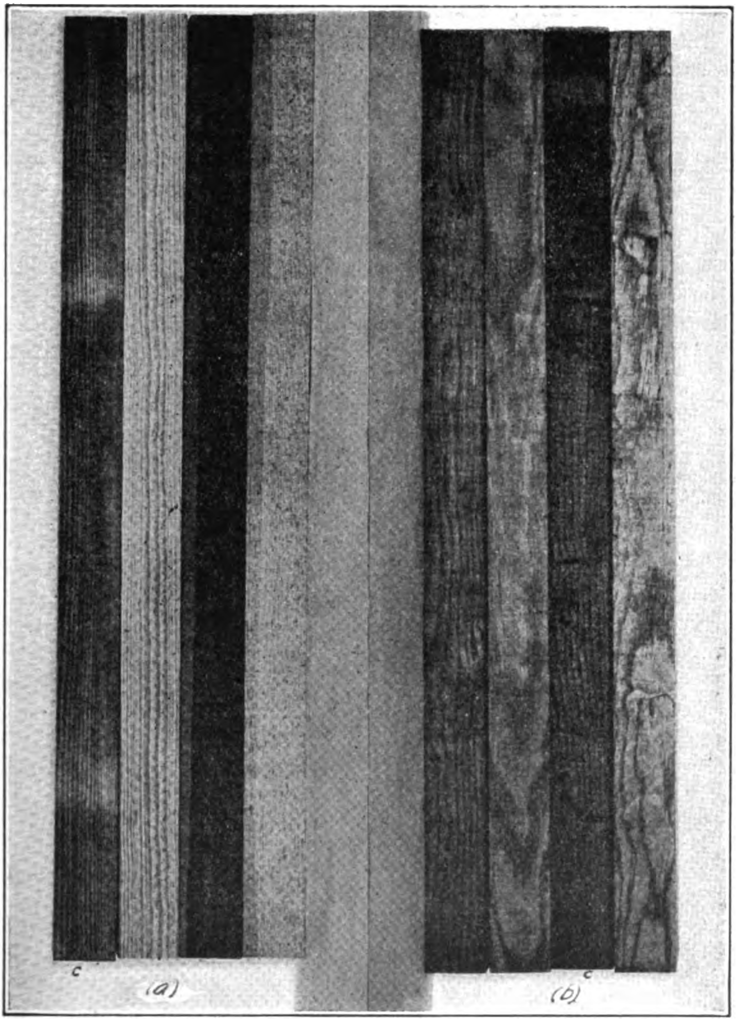
In order to make a trial of the methods proposed for future tests, it was decided to conduct a run at 150° F. for as long a time as possible this year. Accordingly an insulated cabinet was constructed, with the necessary heating apparatus, a series of specimens was impregnated with a 4% solution of zinc chloride salt as received from the manufacturer, and with a corresponding series of blanks or control specimens were subjected for 40 days to 150° F. Nineteen sticks of each kind were placed in the cabinet.

At the end of the 40-day period, 5 of each series were removed and broken by cross-bending to determine their modulus of rupture. The moisture content was also taken. The remaining sticks were left in the cabinet at the same temperature.

The average moisture content of both series of 5 specimens was found to be 2%. The average modulus of rupture of the blanks was 13,700 lbs. per square inch, while that of the treated specimens was 17% less, or 11,300 lbs. per square inch.

From these results we conclude merely that a weakness in the treated timber may confidently be expected, and that the tests should be continued and extended till all the factors entering into such deterioration are known. The number of tests made are too few to place great reliance upon, though with selected specimens as in this case, blanks and treated specimens being selected at random from the same piece of timber, the comparison ought not to be misleading.

After remaining in the heat a short time the appearance of the treated sticks changed in color, turning a dark, dull brown. In places on some sticks it verged on black, and in such places had much the appearance of partially charred wood. To determine just what this action is, it has been suggested for future work that microscopic and chemical studies be made of it.



Typical Specimens (2/7 Actual Size) After Storing About 6 Weeks at 150° F.

(a) Side view.

(b) Bottom view, as placed in cabinet.

[Note photographic action on treated specimens (marked c) and light streak on bottom of one where tie had rested on cleat and was protected from light. Sides which had strong direct rays of light seem to have turned darker than bottoms which were somewhat protected.]

Report on Test of Specimens Stored at 150° F. for Three Months.

This test was conducted partially as a check on the test made on specimens stored at 150° F. for 40 days and also to obtain another set of points for a plot giving curves of relative strength after various storage periods.

Ten specimens were broken in cross-bending and in compression parallel to the grain. The moisture content was also taken. These specimens had been stored at 150° F. and 11% relative humidity for 13½ weeks. Five of them had been impregnated by the method previously described, with an average of 0.59 lb. dry zinc chloride per cubic foot and 5 were untreated.

RESULTS.—The average moisture content of the treated sticks was found to be 1.9%; that of the untreated sticks, 1.6%. This difference is too small to affect appreciably the strength of the wood. The average modulus of rupture of the blanks was 15,950 lbs. per square inch, while that of the treated specimens was 27% less, or 11,400 lbs. per square inch. The unit-breaking load, in compression parallel to the grain, was 13,960 lbs. per square inch for the blanks; for the treated sticks this figure was 8.3% less, or 12,800 lbs. per square inch.

CONCLUSIONS.—These results show a weakening nearly in proportion to time when compared with the 17% reduction in modulus of rupture at the end of 5 weeks. The number of sticks is too small for great reliance to be placed upon these figures. However, the specimens were selected at random from the whole number, and the comparison should not be greatly in error. The trend of the action, at least, seems to be established beyond question by the results of these 2 tests. We must, nevertheless, look to the long-time tests to establish a definite law of strength decrease.

SPECIMENS AND IMPREGNATION.—The 10 sticks used for this test were taken from the set of 150 prepared in November, 1915. The entire set was No. 1 grade North Carolina (loblolly) pine, clear and free from defects, and consisted of sapwood only. The timber was purchased from the Wyman-Allen Lumber Company of Charlestown, and the specimens were prepared and sawed in the Institute carpenter shop. The original pieces, from which the specimens were cut, were 2 ins. x 8 ins. stock, kiln dried. No record was left of the position of the specimens in these sticks.

The 5 treated specimens used in this test, Nos. 7–1–c_1 to 7–5–c_1, were impregnated in a vertical position by the method previously described with an average of 0.59 lb. dry zinc chloride per cubic foot of wood. The zinc chloride was obtained in 5-lb. bottles from the supply room of the Institute chemical laboratory, of the quality known as "commercial zinc chloride." The salt may have been slightly acidic, but this factor may well be expected to enter into the commercial treatment process. The untreated specimens were Nos. 8-1-b_1 to 8-5-b_1.

APPEARANCE OF SPECIMENS.—The treated specimens showed a progressive discoloration during storage in the oven. At the time of this test, the specimens broken were of a dull, dark brown, which varied in intensity at different parts of the sticks. Those portions of the specimens protected from light showed but very slight discoloration. The brown color was considerably darker than that noted in the 5 weeks' test. The untreated sticks showed the original color of the wood.

PENETRATION OF DISCOLORATION.—When the treated sticks were cut in cross-section, it was noticed that the discoloration was very markedly confined to a narrow region extending in from the surface for an average depth of 1/32 in. to 1/16 inch.

Report on Thirteen Months' Test at 150° F.

PURPOSE AND PROCEDURE.—Twenty specimens, 10 treated and 10 untreated, were tested in bending and in compression parallel to the grain. The moisture content was also taken. These specimens had been stored at 150° F. and 11% relative humidity for 57 weeks. The treated sticks had been impregnated with an average of 0.49 lb. dry zinc chloride per cubic foot.

RESULTS.—The average moisture content of the treated specimens was 1.4%; that of the untreated sticks, 1.9%. This difference is too small to have an appreciable effect upon the strength of the wood.

Before presenting the other results of this test, attention should be called to the following facts: The treated sticks Nos. 1-1, 1-4, 1-7, 1-9 and 1-14, and untreated sticks Nos. 1-2, 1-3, 1-6, 1-8, 1-10, 1-13 and 1-15, were cut from 1 piece of lumber, known as "Piece No. 1."

In the same way, treated specimens Nos. 2-2, 2-6, 2-8, 2-10 and 2-13, and untreated specimens Nos. 2-7, 2-9 and 2-12 were cut from "Piece No. 2." Tests showed that the specimens from "Piece No. 2" were uniformly weaker than those cut from "Piece No. 1." Hence, in the treated set there were 5 relatively weak and 5 relatively strong specimens, while among the blanks there were only 3 relatively weak and 7 relatively strong pieces.

This discrepancy, overlooked at the time of testing, would tend to exaggerate the weakening of the treated wood, if the per cent. of strength reduction was based upon the difference between the average strength of the 10 treated specimens and that of the 10 blanks. Therefore, results were separately computed for the specimens from "Piece No. 1" and for those from "Piece No. 2." The 2 sets of results thus obtained were then averaged, giving each the same weight, to obtain the final figures. The following table shows the method of calculation, and the results obtained:

CROSS-BENDING TEST.

	Modulus of Rupture.	
Avg. of 5 treated sticks, (1-1, 1-4, 1-7, 1-9, 1-14)	9,680	Reduction of strength, 30%
Avg. of 7 blanks, (1-2, 1-3, 1-6, 1-8, 1-10, 1-13, 1-15)	13,860	
Avg. of 5 treated sticks, (2-2, 2-6, 2-8, 2-10, 2-13)	4,740	Reduction of strength, 49%
Avg. of 3 blanks, (2-7, 2-9, 2-12)	9,270	

Average reduction of strength, 39.5%.

Report on Tests of Specimens Stored at 150° F. for Two Years.

PROCEDURE.—On March 31, 1917, 7 specimens were broken in cross-bending and in compression parallel to the grain, and their moisture content was determined. These specimens had been stored for 2 years at 150° F., and about 10% relative humidity. Three had been treated with zinc chloride, and 4 were blanks.

RESULTS—The average moisture content of the treated sticks was 1.7%; of the untreated sticks, 2.3%.

Average modulus of rupture of the blanks was 7,470 lbs. per square inch, while that of the treated sticks was 3,806 lbs. per square inch, or 49% less. The unit-breaking load, in compression parallel to the grain, was 9,428 lbs. per square inch for the blanks, and 7,481 lbs. per square inch for untreated sticks, 20.6% less.

These sticks all failed in tension, and were very brittle, the untreated as well as the treated, although the latter were somewhat more sudden in their manner of failure.

The treated sticks were very dark in color, while the blanks retained their natural shade. In the case of the treated sticks the discoloration was general throughout the cross-section, being of greatest intensity at the edges.

An interesting, and perhaps important fact, was observed in the compression test. The blanks failed in the usual manner, but the treated sticks split up into a large number of individual columns, varying in size from a mere splinter to one of about a square inch section.

These little columns failed one at a time, making it hard to tell when the true ultimate load had been reached. After failure, the specimen could easily be picked to pieces with the fingers. When this was done, it was observed that in every case the plane of separation followed a line between the annual rings of the wood.

This phenomenon indicates the path of the chemical into the wood, and seems to show that its action is not restricted to a thin outer layer, as previously thought, but is felt over the entire cross-section.

REPORT ON WATER-GAS TAR.*

BY W. H. FULWEILER.

PRODUCTION.—Out of 917 plants engaged in the manufacture of illuminating gas about 596 manufacture carburetted water gas, which makes up about 70% of the volume of illuminating gas produced.

While about 51% of the number of plants are located along the eastern coast, and about 35% in the Mississippi Valley, yet somewhat over 67% of the gas is manufactured by the plants along the Atlantic coast.

Table 1 gives the production of carburetted water gas, the quantity of oil used, the estimated quantity of water-gas tar produced.

Figures for water-gas tar produced that were obtained in connection with a survey of the gas oil requirements in the United States by a committee of the American Gas Association indicate that at least during the last 2 or 3 years between 70% and 80% of the tar produced is utilized so that for the years 1918, 1919 and 1920, the utilized or available production will be approximately: in 1918, 70,000,000 gals.; in 1919, 75,000,000 gals., and for 1920, 80,000,000 gallons. The figures given in "Mineral Resources for 1918" show only 53,420,000 gallons. This apparently refers to tar sold.

The increase in tar marketed is probably due to the fact that the fuel value of the material has become more widely recognized, as it has been found that water-gas tar can be burned with the same installation as fuel oil and with slightly higher efficiency. This has resulted in a very great increase in the value of the material so that today its market value appears to be from 15% to 20% higher than coal tar.

While there is a tendency to reduce the consumption of gas oil, due to its present scarcity and high price, yet owing to the many advantages that the manufacture of carburetted water gas possesses the production of water-gas tar will continue at about its present rate for a number of years.

PHYSICAL AND CHEMICAL CHARACTERISTICS.—For the purpose of this discussion we may consider 3 distinct tars: tar produced by the destructive distillation of coal, which we will call "coal tar"; tar produced by what may be called the destructive distillation of natural hydrocarbons (petroleum) in its own products of decomposition, which we will call "oil tar"; and tar produced by the destructive distillation of oil in the presence of a mixture of hydrogen or hydrogen and carbon monoxide and water vapor, known as blue gas, which we will call "water-gas tar".

The resulting tars from these 3 processes are the summation of all of the manifold and complicated reactions which may take place as the result of heating a mixture of hydrocarbons (as we may consider coal a mixture of hydrocarbons) to high temperatures.

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* This paper was submitted as a part of the report of Committee No. 4—Preservatives.

The physical and chemical qualities of the tars reflect quite accurately the variations in the fundamental factors which govern all reactions, that is, pressure, temperature, time of contact, concentration, and the presence of catalytic substances.

In connection with the tables giving analyses of tars it must be remembered that this material is somewhat variable in its composition and that an analysis can only represent the particular sample tested. However, the analyses given are fairly representative of materials available at the date of this report.

Table 2 gives analyses of samples of horizontal, vertical and coke-oven coal tars and water-gas tar.

Table 3 gives the analyses of samples of coal-tar creosote, water-gas tar creosote and Mexican crude oil.

Table 4 gives the analyses of some water-gas tars made from different oils and under different manufacturing conditions, which show the probable range in composition that may be expected.

It will be noted that for a given boiling point the gravities and refractive indices in the water-gas tar are lower than in coal tar, and the gravities of the oil tar are in turn lower than in the water-gas tar.

QUALITIES OF WATER-GAS TAR AS AFFECTING ITS PRESERVATIVE QUALITY.—It would seem that there are 4 fundamental qualities that affect the value of any material for its use as a wood preservative. These are penetrance, or the ability to get the material into the wood; permanence, or its ability to stay in the wood; waterproofing effect, and toxicity.

It appears from the work of E. Bateman[1] that penetrance bears some close relation to the absolute viscosity of the material at the temperature employed in the treating process.

Another factor that may be of importance is surface tension. Table 5 gives a number of determinations of absolute viscosity and surface tension at 2 temperatures of a number of samples of commercial materials.

As a result of practical experience it has been found that water-gas tar derivatives whether refined tar, distillates or mixtures, appear to give very satisfactory penetration. In fact, it is possible to secure very complete penetration of wood blocks with refined water-gas tar having a gravity of 1.14 and a specific viscosity as high as 2.4 at 100°C., and a very considerable yardage of wood block has been laid with such material.

The permanency of the material in the wood will probably be affected by 3 factors—evaporation of the material, leeching, and changes in the chemical composition. As it will be noted from the comparative analyses of water-gas tar and coal tar, that with 2 fractions of same gravities, the boiling point of the water-gas tar will be considerably higher than the corresponding coal tar, so that it is to be expected that the loss in evaporation which depends upon vapor tension should be slightly lower with water-gas-tar oil than with coal-tar oils of the same gravity. Laboratory tests have in general confirmed this.

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[1] "Relation Between Viscosity and Penetrance of Creosote into Wood," by E. Bateman, Chem. & Met. Eng., Vol. 22, No. 8 (1920).

Table 6 gives some analyses of material extracted from wood blocks and railroad ties that have been in service from 4 years to 10 years.

It is hardly within the province of this report to discuss the validity of the laboratory petri-dish test for toxicity as affecting the practical suitability of the material for preservation purposes. The work of Dean & Downs[2], Weiss[3] and Humphrey & Fleming[4] on this subject are well known and are given in Table 7. The summation of the results that have been reported appear to indicate at least with the lower gravity water-gas tar distillate that the amount of creosote that is used per cubic foot in commercial practice is in excess of that required to inhibit the growth of fungi.

Many factors that cannot be duplicated in the laboratory appear to enter into the question of inhibiting the growth of wood-destroying fungi under practical conditions so that the petri-dish test, while valid for the particular conditions may be of little value in determining the practical suitability for commercial use.

Practical experience with authenticated samples of water-gas tar have shown that, for instance, in wood block, no decay has taken place in 12 years, and in railroad ties no decay has taken place in 10 years, and it is believed that these practical tests are much more indicative of the suitability of the material than the petri-dish tests before mentioned.

ADAPTABILITY TO USE IN WOOD-PRESERVING PROCESS.—Water-gas-tar products have been used commercially in the full-cell, Rueping and Card processes with entirely satisfactory operating results.

In some of the earlier work it was attempted to duplicate the gravity of the coal-tar creosote by using high-gravity water-gas-tar distillates. This required a distillation to coke in order to secure the high gravities. Later it was found more advantageous to use mixtures of refined water-gas tar and lower-gravity distillate oil. In Table 8 are given some analyses of water-gas-tar distillates that have been used commercially, principally in the treatment of railroad ties and cross-arms.

In the full-cell process for wood block, refined tars having gravities as high as 1.14 have given satisfactory penetration. Some typical analyses of such material are given in Table 9.

For railroad ties, the best results with both the full-cell and Rueping processes have been obtained with a mixture of about equal parts of refined tar and distillate, so that the gravity of the mixture was from 1.04 to 1.07 at 38°C. In this manner, any advantage that may accrue with a higher toxicity of the lighter oils is secured together with the very high penetration, and at the same time the very complete waterproofing effect of the refined tar is secured. Some typical analyses of this material are shown in Table 10.

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[2] Dean, A. L., and Downs, C. R., "Antiseptic Tests of Wood-Preserving Oils," 8 Int. Cong. Appl. Chem., Vol. 13, sec. 6a, page 103.

[3] Weiss, J. M., "The Action of Oils and Tars in Preventing Mould Growth," J. Soc. Chem. Ind., Vol. 30, pages 190 and 1348 (1911).

[4] Humphrey, C. J., and Fleming, R. M., "The Toxicity to Fungi of Various Oils and Salts, Particularly Those Used in Wood-Preserving." Bulletin No. 227, U. S. Dept. of Agriculture.

In the Card process, where the wood is treated with a mixture of the oil and a zinc chloride solution, some unsatisfactory results have been obtained where crude water-gas tar was used. This resulted in the deposition of a heavy black sediment that collected on the surface of the treated material, making it very disagreeable to handle, and also collected in the bottom of the retorts and working tank. Such precipitation, however, is not noticed in properly prepared and refined water-gas-tar products.

It is advantageous to hold the percentage of heavy hydrocarbons, that is, those boiling above 355°C., to less than 40%, and in order to obtain this figure a mixture of distillate oil and refined tar is usually required. Representative analyses of material that have given very satisfactory results are shown in Table 11.

EXTENT OF USE.—The amount of water-gas tar reported to the United States Forest Service as used in wood-preserving is somewhat low, as the amount sold by one company alone has exceeded the published figures. This may be due, however, to the inclusion of a certain amount of water-gas tar in the paving oil reported. Table 12 gives the figures as they have been reported since 1915.

The water-gas tar derivatives have been used in practically every branch of the wood-preserving industry. Its authenticated commercial use in treatment of railroad ties began in 1910, when the Public Service Railway Company of New Jersey began to use it in a regular 10-lb. treatment on their ties. They probably have in track 500,000 ties treated with water-gas tar.

Its use by steam roads began in 1914, when one of our larger railroads began to use it. Since then water-gas tar has been used by the Baltimore & Ohio, Chicago, Burlington & Quincy, Pennsylvania, and the Philadelphia & Reading railroads. The Baltimore & Ohio and the Chicago, Burlington & Quincy railroads have used water-gas tar in the Card process, the Philadelphia & Reading and the Pennsylvania have used it in the full-cell and Rueping processes.

The Baltimore & Ohio has treated approximately 5,000,000 cross-ties with the Card process, using ½-lb. zinc chloride with 3 lbs. water-gas tar.

The Chicago, Burlington & Quincy has treated about 171,000 ties with water-gas tar and zinc chloride solution.

The Philadelphia & Reading and the Pennsylvania railroads have used water-gas tar in admixtures with coal-tar products in varying percentages from 10% up to straight water-gas tar.

In wood-block paving very considerable quantities of water-gas tar have been used, either alone or with a mixture of coal tar that for commercial reasons have not been reported as such.

The authenticated use of the material commenced in 1907, and a very considerable yardage of wood block has been laid by the Barber Asphalt Company, which was treated with refined water-gas tar.

The details of the paving laid with water-gas-tar-treated wood blocks are given in Table 13. In addition to the yardage given, there is probably an equal yardage that could not be reported.

In structural material the Committee has had difficulty in getting authentic figures due to various commercial considerations. The United Gas Improvement Company of Philadelphia, has been operating a small treating plant since 1911, where it has been treating considerable quantities of structural timber for local use. Examination of the records indicates that this material has been used principally for docks, wharves and trestles. Considerable quantities have been used at the coast resorts near Philadelphia, such as Atlantic City, Ocean City, etc., where mild attacks from marine borers are expected.

In marine work, except as before noted, the Committee could find but little commercial use of water-gas tar. Some tests with piles and test-pile sections have been made, but no extensive use has been found.

In miscellaneous materials, very considerable quantities of refined water-gas tar have been used in the middle west for treatment of fence posts. A number of electric light companies have treated cross-arms for the past 10 years with a brush treatment of water-gas-tar distillate of about 1.04 gravity. Blocking for use under gas mains and cross-arms have been treated by pressure treatment with a distillate and refined tar of 1.06 gravity. Water-gas-tar products have also been extensively used in the treatment of wood conduit.

SERVICE RECORDS.—The records of 24,000 railroad ties in the lines of the Public Service Company of New Jersey, treated in 1911, 1912, 1913 and 1914, are being reported from year to year in the American Railway Engineering Association's Proceedings, and are summarized in Table 14.

The Forest Products Laboratory and the Baltimore & Ohio Railroad are carrying on some service-tests at the Herring Run test track near Baltimore, Md. See Table 15.

In wood block, the yardage reported by the sub-committee in 1917 is being kept under inspection, and is summarized in Table 13.

In addition, there are some water-gas-tar blocks in the test-pavement on Second Avenue, New York City, half-way between Sixth Street and the north property line of Seventh Street, between Fourteenth and Fifteenth Streets, and between Eighteenth and Nineteenth Streets. They were reported on in the PROCEEDINGS.[5]

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[5] Proceedings, A. W.-P. A., 1919, Page 99.

The Forest Products Laboratory has service records of a number of fence posts treated with water-gas tar that are summarized in Table 16.

Teesdale[6] has reported some experiments of the Forest Products Laboratory with test-pile sections treated with water-gas tar at Gulfport, Miss., and San Diego, Cal., for test against marine borers. It is also understood that some test-pile sections were installed at Brunswick, Georgia.

In 1910 some extensive tests were made with mine timbers, but the Committee is unable to secure final reports on these.

SPECIFICATIONS.—A number of specifications have been in commercial use for the purchase of water-tar products. These covered several qualities of refined tar, distillates, and mixtures of distillates and refined tar. These specifications are given in Table 17.

Summary.

There exists, and will continue to exist, for a number of years, a large amount of water-gas tar that could serve as a potential source of preservative oil.

Water-gas tar is in general composed of the same aromatic hydrocarbons as coal tar, but it does not contain phenoloid bodies, and only contains traces of nitrogen bases.

Water-gas-tar products have been found satisfactory in commercial practice in their ability to penetrate wood, to remain in wood, to render it waterproof, and to prevent decay.

Practical experience indicates that water-gas-tar products can be used satisfactorily in the full-cell, Rueping and Card processes.

During the last 13 years railroad ties, wood-paving blocks, timber for docks, cross-arms, and fence posts treated with water-gas tar have been in satisfactory and successful use.

TABLE 1.

Year	Carburetted Water Gas Made.	Gas Oil Used.	Estimated Water-Gas Tar Produced.
	M. Cu. Ft.	*Gallons.*	*Gallons.*
1915	136,333,000	553,238,000	83,000,000
1918	191,741,000	703,823,000	111,000,000
1919	194,217,000	709,327,000	111,500,000
1920 (Estimated)	214,217,000	769,607,000	115,500,000

TABLE 2.

	Horizontal.	Vertical.	Coke Oven.	Water-Gas Tar.
Specific gravity at 38°C.	1.2357	1.1300	1.1700	1.1010
Free carbon (% weight)	28.6	5.5	5.5	2.0
Tar acids (% volume)	5.4	13.2	6.0	None
Naphthalene (pound)	0.82	0.12	0.35	......
Distillation (% weight):				
210°C.	0.5	7.5	0.1	3.0
235°C.	4.8	17.5	3.7	14.0
315°C.	20.9	39.0	33.0	42.0
355°C.	28.1	50.2	45.3	55.0
Coke (% weight)	44.9	23.2	22.4	24.1
Sp. gr., 235°C.-315°C. fraction	1.0377	1.0010	1.0320	1.001
Sp. gr., 315°C.-355°C. fraction	1.1051	1.061	1.1060	1.05
Unsulphonated material (% weight)	0.4	2.3	0.2	3.1

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[6] Teesdale, C. H., "Efficiency of Various Parts of Coal-Tar Creosote Against Marine Borers," Eng. Record, 70, page 302. (1914).

TABLE 3.

	Water-Gas-Tar Creosote Solution.			Coal-Tar Creosote.			Mexican Crude Oil.		
H_2O, (% volume)	0.7			8.6			2.3		
Free carbon (% weight)	0.48			2.41			Trace.		
$C_{10}H_8$ " "	2.99			14.05			Nil.		
Tar acids (% volume)	0.54			0.82			1.01		
Sp. gr. at 38°C	1.0579			1 0477			0.9440		
Unsulph. matter (% volume)	3.40			0.80			54.12		
	DISTILLATION (A. R. E. A.)—								
Temperature.	% Wt.	Sp. Gr.	Ref. Ind.	% Wt.	Sp. Gr.	Ref. Ind.	% Wt.	Sp. Gr.	Ref. Ind.
Up to 200°C	1.6	.9213	1.5355	5.0	.9451	1.5483	7.0	.7436	1.4236
200 " 210	1.6	.9317	1.5449	6.1	.9651	1.5638	2.0	.7568	1.4340
210 " 235	10.6	.9540	1.5600	9.7	.9828	1.5754	3.9	.7801	1.4390
235 " 315	34.7	.9860	1.5859	40.2	1.0189	1.6057	11.3	.8129	1.4564
315 " 355	15.6	1.0324	1.6193	19.0	1.0829	1.6510	9.3	.8517	1.47633
Residue	34.0	1.2253	....	19.8	1.887	....	66.4	1.0037	....
Total	98.1			99.8			99.9		

TABLE 4.—ANALYSES OF WATER-GAS TARS.

Sp. gr. at 25°/25°C.	1.083	1.090	1.108	1.125
Sp. gr. at 38°/15.5°C.	1.070	1.077	1.092	1.108
Free carbon, CS_2. (% weight)	0.7	1.2	1.5	2.0
Free carbon hot C_6H_6, (%weight)	1.7	2.1	2.7	2.7
Coke (% weight)	16.6	16.8	19.6	20.8
Distillation (A.R.E.A.)—				
Water (% volume)	1.7	5.3	4.8	3.4
Total oil to 210°C. (% weight)	7.0	6.8	4.2	1.6
" " " 235°C. (" ")	16.4	15.6	9.0	5.1
" " " 315°C. (" ")	41.4	40.4	36.0	30.1
" " " 355°C. (" ")	51.9	50.9	47.5	39.6
Float, 70°C. secs. Res. Ab. 355°C.	Over 20 min.	Over 20 min	Over 20 min.	Over 20 min.
Sp. gr. at 38°/15.5°C.—				
Total oil to 210°C.	.9017	.9039	.9082	.927
" " " 235°C.	.9478	.9387	.9430	.9517
" " " 315°C.	.9833	.9854	.9833	.9932
" " " 355°C.	1.0278	1.0300	1.0404	1.0354
Refractive Index—				
Total oil to 210°C.	1.5315	1.5300	1.5340	1.5530
" " " 235°C.	1.5594	1.5525	1.5580	1.5640
" " " 315°C.	1.5865	1.5846	1.5875	1.5950
" " " 355°C.	1.6170	1.6198	1.6282	1.6235
Unsulphonated material (% weight)	4.1	3.3	3.2	2.2

TABLE 5.—SURFACE TENSION AND ABSOLUTE VISCOSITIES OF COMMERCIAL PRESERVATIVE MATERIALS.

Grade	Distillate.	Distillate.	Solution.	Distillate.	Distillate.	Distillate.	Solution.	Ref. Tar.
Specification	A.W.-P.A.	A.R.E.A. No. 3.	A.W.-P.A.	Light.	N.E.L.A.	Heavy.	A.R.E.A.	Wood Block.
Sp. gr. at 38°C	1.101	1.050	1.120	1.022	1.041	1.070	1.046	1.103
Free carbon	0.1%	0.3%	1.1%	0.01%	0.05%	0.01%	1.34%	1.6%
Water	None.	None.	None.	None.	None.	None.	2.8	3.2
Distillation:								
205°C	....	....	....	0.7%	"	"	....	....
210°C	0.5%	2.4%	0.2%	1.2	....	"	3.3	2.2
235°C	8.4	34.6	2.7	8.7	2.0%	"	10.6	9.2
315°C	....	72.7	29.7	62.5	55.0	22.8%	52.7	36.2
355°C	....	92.0	46.4	81.5	....	....	63.6	47.2
Float in residue	14.2"	29.9"	22.0"	Soft.	....	Soft.	42"	20'
Coke	0.63%	2.2%	5.2%	0.6%	0.7%	0.9%	8.4%	19.6%
Sp. gr., 235°C.-315°C	1.039	1.025	1.027	0.9895	0.9985	1.0115	0.9830	0.9920
Sp. gr., 315°C.-355°C	1.098	1.085	1.099	....	....	....	....	....
Unsulphonated material	....	....	....	3.9	3.7	1.4	1.7	2.3
Sp. gr. at 50°C	1.0984	1.0387	1.1054	1.0067	1.0227	1.0608	1.0358	1.0900
Absolute viscosity	.079212	.030812	.120604	.025413	.033878	.07283	.08346	.433343
Surface tension	39.136	36.009	39.068	33.721	33.244	36.393	35.031	33.911
Sp. gr. at 80°C	1.0722	1.0169	1.0851	.9853	1.0013	1.0405	1.0155	1.0689
Absolute viscosity	.033627	.016859	.046237	.015588	.018480	.032507	.03763	.1189903
Surface tension	35.098	31.270	36.348	30.964	31.692	33.964	32.063	31.500

Viscosity determined with Bingham's apparatus.
Surface tension determined by capillary rise.

TABLE 7.—TOXICITY TESTS ON WATER-GAS-TAR PRODUCTS.

Oil.	Gravity.	Organism.	Toxic Point.	Culture Medium.	Time.	Observers.
170° C.-340°C.	....	Polystictus	0.40%-0.45%	Agar	....	Dean & Downs.
200° C.-350°C.	....	Versicolor	0.35	"	....	" "
170° C.-315°C.	1.024 @ 15.5°C.	Penicillium	2.00	"	4 weeks	Weiss.
210° C.-315°C.	1.053 @ 15.5°C.	"	+10.00	"	4 "	"
	1.058 @ 60°C.	Formes Annosus	+40.00	"	4-8 "	Humphrey & Fleming
	1.058 @ 60°C.	Formes Pinicola	+40.00	"	4-5 "	" "
	.995 @ 60°C.	Formes Annosus	0.65	"	5-8 "	" "

Table 8.—Analyses of Distillate Water-Gas-Tar Oils.

Sp. gr. at 38°/15.5°C.	1.027	1.036	1.058	1.076
Water (% volume)	0.7	0.8	0.8	Nil.
Free carbon (% weight)	0.25	0.2	0.22	.15
Distillation—				
210°C. (% weight)	6.02	5.8	4.7	.7
235°C. (“ “)	12.1	14.1	10.1	1.6
315°C. (“ “)	47.4	52.0	35.4	10.1
355°C. (“ “)	77.7	71.0	58.3	46.0
Residue	Soft	Soft	Liquid	Liquid

Table 9.—Refined Water-Gas Tar for Wood Blocks.

Sp. gr. at 38°/15.5°C.	1.0900	1.1100	1.1310	1.1400
Insoluble in benzol & chloroform (% weight)	1.02	0.90	0.90	0.58
Distillation—				
210°C. (% weight)	4.5	2.4	Trace	Trace
235°C. (“ “)	17.0	9.8	2.2	1.6
315°C. (“ “)	45.5	31.4	28.2	25.3
355°C. (“ “)	65.5	47.0	43.7	38.5
Sp. gr. of entire distillate at 38°/15.5°C.	.9885	.9950	1.0050	1.0130

Table 10.—Distillated and Refined Water-Gas-Tar-Creosote Solution.
(This material was made to meet Specification D in Table 17.)

Sp. gr. at 38°/15.5°C.	1.045	1.047	1.045
Free carbon (benzol) (% weight)	1.03	1.54	1.40
Distillate—			
210°C. (% weight)	2.60	3.30	3.60
235°C. (“ “)	8.10	10.60	15.70
315°C. (“ “)	53.70	52.70	51.00
355°C. (“ “)	69.50	63.60	63.80
Float-test on residue at 70°C. (inches)	26.1	41.7	36.4
Sp. gr., 235°C.-315°C. fraction at 38°/15.5°C.	.9817	.9820	.9917
Sp. gr., 315°C.-355°C. fraction at 38°/15.5°C.	1.040	1.034	1.043
Coke (% weight)	4.8	8.4	5.8

Table 11.—Analyses of Distillate Refined Water-Gas-Tar-Creosote Solutions.
(These materials were used in the Card process).

Sp. gr. at 38°/15.5°C.	1.045	1.051	1.062
Free carbon (% weight)	1.2	1.4	1.7
Oil to 200°C. (“ “)	3.9	3.1	0.7
210°C. (“ “)	7.1	4.7	1.4
235°C. (“ “)	16.0	9.5	7.8
355°C. (“ “)	67.0	65.0	63.5
Residue above 355°C.	Soft	Soft	Soft

(The following were used in the Rueping process).

Sp. gr. at 38°/15.5°C.	1.045	1.050	1.055
Free carbon (% weight)	0.88	1.47	1.63
Distillate—			
210°C. (% weight)	3.0	3.5	3.1
235°C. (“ “)	8.2	13.0	11.3
315°C. (“ “)	36.2	38.2	36.5
Water (% volume)	0.5	1.0	1.2

Table 12.

Year.	Total Creosote.	Foreign Creosote.	Domestic Coal Tar.	Water-Gas Tar.	Paving Oil.	Misc. Materials.
	Gallons.	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*
1915	80,859,442	37,501,007	41,333,890	2,024,545	3,205,563	1,693,544
1916	90,404,749	43,649,931	45,318,735	1,436,083	5,675,095	582,754
1917	75,541,737	18,259,141	54,305,204	2,977,392	7,579,819	137,361
1918	52,776,386	2,165,736	47,787,998	2,822,652	4,057,862	28,013
1919	65,556,247	6,493,974	55,579,512	3,482,761	2,412,592	102,011

TABLE 13.—LOCATION OF WOOD BLOCK TREATED WITH WATER-GAS TAR.

City.	Location.	Square Yards (Approximate.)	Absorption per Cu. Ft. of Lumber.
	1908.		Pounds
Boston, Mass	Washington St., from 78' south of Court Ave., to Cornhill and State Sts., N. & S. of Old State House	1300	20
Pittsburgh, Pa	6th St. bridge, between Pittsburgh and Allegheny	3228	20
Havana, Cuba	Shop flooring	4800	20
New York	Rogers Place, from Dongan to 165th St	2975	20
" "	Minford St., Boston Road to Jennings	4541	20
" "	Charlotte St., Boston Round to Jennings	3644	20
" "	Liberty Street Terminal	1260	20
Waterbury, Conn	Intersection of West Main and Willow Sts		20
	1909.		
Boston, Mass	Bowdin Street	1583	20
" "	Falsmouth	1435	20
Holyoke, Mass		1868	20
Oakmont, Pa	Bridge floor	3915	16
	1910.		
Asbury Park, N. J.	Flooring, from bridge at Deal Lake	2038	16
South Boston, Mass.	Milk St., Pearl St. to Oliver St., Pearl St., Milk St. to 148 ft. north	2353	20
	Oliver St., Milk St. to 200' southeast	4860	16
Philadelphia, Pa	Flooring pier No. 34, South wharves	4860	16
Eddystone, Pa	Baldwin Locomotive Works machine shop flooring	7137	16
	1911.		
Newark, N. J	Plant Road bridge over Passaic River	2562	20
Bridgeport, Conn	State St., Broad St. to Fairfield Ave	24433	16
Boston, Mass	Milk St., Oliver St. to Broad St	1096	20
" "	Washington St., Williams St. to Dudley St	4300	20
" "	Ferdinand St., Fayette St., to B. & A. R. R., Fayette St., Ferdinand St. to Pleasant St., Melrose St., Ferdinand St. to Pleasant St Church St., Melrose St. to Fayette St	5230	20
	1912.		
Cambridge, Mass	Mass. St., Brattle Sq. to Bigelow St Harvard Sq., Brattle Sq., to subway entrance, including Mount Auburn St. Brattle Sq., Lafayette St. to Mass. St.	27514	20
Philadelphia, Pa	33rd St., Race St. to Powelton Ave 48 St., Woodland Ave., to Gray's Ferry Road. Woodland Ave., 48th St. to P. & W. G. R. R.	2928	18
Philadelphia, Pa	Wallace St., 18th St. to 19th St Hamilton St., 18th St. to 19th St. Hamilton St., 20th St. to 21st St.	3683	18
E. Cambridge, Mass	Harvard bridge	9509	20
(*)New York	2nd Ave., 18th St. to 19th St		16
	2nd Ave., 14th St. to 15th St., North from 14th St. East Side		20
	2nd Ave., South of 7th St		20
(†)Philadelphia, Pa	Arch St., Front to 21st St	40,000	18
(*)According to specifications.	(†)According to analysis.		
	1913.		
Waterbury, Conn	Bank Street	2030	20
Dorchester, Mass	Washington St., Blue Hill Ave., to Talbot Ave.	10130	20
New Britain, Conn	West Main Street	7300	20
Pittsfield, Mass	Columbus Ave	4000	20

TABLE 13.—LOCATION OF WOOD BLOCK TREATED WITH WATER-GAS TAR (Concluded.)

City.	Location.	Square Yards. (Approximate.)	Absorption per Cu. Ft. of Lumber
	1914.		Pounds
Fitchburg, Mass	Main St., Pritchard St. to Railstone St. Pritchard St., Main St. to Pleasant St. Railstone St., Main St. to Bridge. Water St., 4th St. to 7th St.	4000	20
Ansonia, Conn	Main St., Bridge St. to brass factory	9627	20
Meriden Conn	No. Colony St. steam railroad to 20 ft. north of Wilcox Avenue	3000	18
Jersey City, N. J.	Washington St., Montgomery St. to Grand St.	1190	20
Philadelphia, Pa	Locust St., Broad St. to 13th St	1550	18
" "	Fifth St., Girard Ave., to 443 ft. southward	1695	18
" "	11th St., Market St., to Chestnut St	1410	18
" "	10th St., Market St. to Chestnut St	1407	18
" "	9th St., Market St. to Chestnut St	1363	18
Jersey City, N. J.	York St., Van Verst St. to 225 ft. east on Washington St	4620	20

TABLE 14.—RECORD OF TIES TREATED WITH WATER-GAS TAR.
(All in lines of Public Service Co., of New Jersey.)

Line.	Location.	Number of ties.	Ballast.	Treatment
	1911.			Lbs. per Cu. Ft.
Blackwood	Brewer's Crossing to Woodbury City Line	1735	Cinder	10
Mantua	Toll Gate to Mantua	24	Cinder and Sand	10
Woodbury	Crown Point Road to "S" Curve, both tracks	512	Cinder	10
Riverton	Erato's property west on River Road	261	Sand	10
	1912.			
Blackwood	Almonesson to Brewer's Crossing	2472	Cinder and Sand	10
Mantua	Toll Gate to Mantua	3940	Cinder	10
National Park	Washington Park to National Park.	1241	Dirt	10
Pensauken	44th and Elm Sts. to Pensauken Junction	3109	Cinder	10
Riverton	Pensauken Junction to No. 4 Turnout	5203	Stone	10
Haddon Heights	King's Highway towards Orston Station, Audubon northbound track	134	Cinder	10
	1913.			
Haddon Heights	Northbound track from sub-station in Haddon Heights to Clements Road, Barrington	612	"	0
Haddon Heights	Northbound track from Warnick Ave. to curve north of Clew's Landing Road	896		
Haddon Heights	Northbound track from the south end of Stratford turnout to Linden Ave., Laurel Springs	978	"	
	1914.			
Riverside	Ford's Lane turnout, Mansfield Township	148	"	
Haddon Heights	Newton Ave. from Beechwood Ave. to Park Ave., Oaklyn	2500	Macadam.	

TABLE 15.—RECORD OF TIES TREATED WITH WATER-GAS TAR INSTALLED IN 1914 IN HERRING RUN TRACK, BALTIMORE, MD.

Number of Tie.	Preservative	Average Absorption. *Lbs. per cu. ft.*	Number Treated.	Number in Test.
1501–1650	W.G.T. Creosote	5.16	150	150
1651–1800	“ “	6.12	150	150
1801–1950	“ “	7.09	150	150
1951–2100	“ “	10.9	150	148
2701–3000	Modified Card (W.G.T.	1.35		
	Creosote—	0.37		
	Zn. Cl_2)	0.59	300	300

TABLE 16.—FENCE POSTS TREATED WITH WATER-GAS TAR. SERVICE RECORD FOREST PRODUCTS LABORATORY.

Species.	Number.	Treatment.	Preservative.	Year.
Bass	51	Open-tank	Water-gas tar	1908
Beech	6	“ “	Water-gas-tar creosote	1908
Birch	6	“ “	“ “ “ “	1908
Alpine fir	10	Brush	Water-gas tar	1911
“ “	10	Open-tank	“ “ “	1911
Black gum	3	“ “	“ “ “	1908
Red oak	100	“ “	Water-gas-tar creosote	1908
“ “	53	“ “	Water-gas tar	1908
Lodgepole pine	60	“ “	“ “ “	1912
“ “	20	Brush	“ “ “	1912
Scrub pine	14	Open-tank	“ “ “	1908
Poplar	6	“ “	Water-gas-tar creosote	1908
Engelmann spruce	60	“ “	Water-gas tar	1912
“ “	20	Brush	“ “ “	1912
Sycamore	9	Open-tank	Water-gas-tar creosote	1908
Willow	9	“ “	“ “ “ “	1908

TABLE 17.—SPECIFICATIONS FOR WATER-GAS TAR PRODUCTS.

DISTILLATE OILS.

	A	B	C
Specific gravity at 38°C	Not less than 1.02	1.03–1.08	Not less than 1.05
Free carbon benzol (% weight)	Not over 1	Not over 1	Not over 1
Water (% volume)	“ “ 3	“ “ 2	“ “ 3
Distillation—			
Oil to 205° C. (% weight)		“ “ 2	
210° C. (“ “)	“ “ 5		“ “ 5
235° C. (“ “)	“ “ 25	“ “ 10	“ “ 10
315° C. (“ “)		“ “ 60	“ “ 60
355° C. (“ “)	Not less than 65		
Coke (“ “)	Not over 2	“ “ 2	“ “ 2
Sulphonation residue (% weight)		“ “ 5	“ “ 5
Float-test on residue above 355°C. at 70°C. (inches)	Not over 50		
Sp. gr. of fraction 235°C.-315°C	0.98–1.02		0.98–1.02

REFINED TARS AND SOLUTIONS.

	D	E	F
Specific gravity 38°C	1.03–1.07	1.05–1.08	1.10–1.14
Free carbon benzol (% weight)	Not over 2	Not over 2	Not over 2
Water (% volume)	“ “ 3	“ “ 3	“ “ 3
Distillation—			
Oil to 210°C. (% weight)	“ “ 8	“ “ 5	“ “ 5
235°C. (“ “)	“ “ 20	“ “ 15	“ “ 15
315°C. (“ “)		“ “ 60	“ “ 40
355°C. (“ “)	Not less than 60		Not less than 25
Coke (“ “)	Not over 10		
Float-test on residue, above 355°C. at 70°C. (inches)	“ “ 50		
Sp. gr. of fraction 235°C.-315°C. at 38°/15.5°C	0.98–1.02		0.98-1.02

A—Commercial light distillate.
B—National Electric Light Association.
C—Commercial heavy distillate.
D—A. E. R. A., 60 % distillate solution.
E—Commercial 50 % distillate solution.
F—Refined tar for wood block.

DR. A. L. KAMMERER: I might add here that the Committee has done a great deal of very long and tedious laboratory work in connection with the compiling of the tables and information on physical characteristics of zinc chloride, and the Chairman wishes to take this occasion to express his thanks for the hearty co-operation of his fellow members on the Committee, because they have certainly worked long and faithfully in getting the data together. I thank you. [*Applause.*]

THE CHAIRMAN: The Report of the Committee on Preservatives is now open for discussion. I think this is one of the best reports ever presented to this Association. Its work on zinc chloride is especially good, something that we have needed for a long while and something we ought to have had long ago, but it took this Committee to put it across. Let us have a full discussion on this report.

MR. C. E. GOSLINE: I move the adoption of the recommendations that the Committee has made, and the acceptance of the report as information. I think it is befitting that the Association extend its hearty thanks for the work that has been done by this Committee.

MR. W. H. KIRKBRIDE: I wish to second that motion, and in so doing to say that this is a most instructive report. I am a comparatively new member of this organization, and if this is a sample of the reports that are being issued by this Association, then I wish to compliment this Association as well as the Committee. It is mighty fine.

THE CHAIRMAN: It has been moved and seconded that the report be accepted with the recommendations the Committee has given us. I would like to call your attention to this fact, that it is unconstitutional to do this where the information has not been distributed to our members 15 days before the annual meeting. It was not possible to get the Preservative Report printed and distributed 15 days before the annual meeting. However, the iodine-potassium ferricyanide-starch method has been published for over a year. Whether you think we should consider that as publication of the Committee report, I do not know, but as for being able to have you submit the recommendation by letter-ballot, I cannot see how we can do that, because the Constitution explicitly states that the matter must be distributed at least 15 days previous to the annual meeting. We do not want to go astray of our by-laws. A little discussion would be in order.

DR. A. L. KAMMERER: I do not believe it would be stretching a point to consider the iodine-potassium ferricyanide-starch test as having already been presented to the Association, because it was read and discussed last year. I do not believe that would be grasp-ing the straw of technicality. I would recommend that it be presented for adoption.

THE CHAIRMAN: Would it be satisfactory to all of you to have that motion include only the one recommendation, the method for the starch test? Otherwise, I do not see how we can go ahead with this unless we limit it to that one recommendation.

MR. O. C. STEINMAYER: Since the second recommendation of the Committee is nothing more than a revision of the standard ferrocyanide method of analysis, I think that action can be taken by the convention at this time.

THE CHAIRMAN: I want to get discussion on this point. We want to be clear on what we are doing.

MR. L. C. DREFAHL: Mr. Chairman, as Mr. Steinmayer says, it is only a very slight change from our standard practice; you are neither adding anything new nor taking anything out, and inasmuch as we are injecting no uncertainty into the matter I do not see but that we are pretty safe to consider the matter.

MR. WALTER BUEHLER: Mr. Chairman, I believe we do not want to be technical about this matter. At the same time there might be a question of establishing a precedent, which at another meeting might be very embarrassing. It is true that this revision is very slight, but at another convention revisions which would be anything but slight might come before the convention with the precedent established at this time on which we might have to take similar action. Personally, I, of course, have no objection to the adoption of this method, but I am just simply pointing out the danger of establishing a precedent.

MR. O. C. STEINMAYER: Mr. Chairman, I think the view to take in the matter is this: Suppose a committee makes a report and it is amended by the Association at the time of the convention, certainly the convention is not going to refuse to accept that committee's report for adoption in the MANUAL. Now, this revision is something similar to that.

THE CHAIRMAN: Any more discussion on this subject?

DR. A. L. KAMMERER: I might say that really it is not a matter of very great weight if it is going to involve a possible violation of our regulations. The information will be published in the PROCEEDINGS, and will be available for reference. I believe rather than run the risk of doing something unconstitutional we had better lay it over until next year.

THE CHAIRMAN: With that understanding I will be very glad to have Mr. Gosline make a new motion suggesting that the iodine-potassium ferricyanide-starch test for determining zinc chloride penetration be submitted to letter-ballot according to Section 2 of Article X of the Constitution, which says:

> "The reports of committees embodying such proposals shall be in order for discussion at an Annual Meeting and shall be referred to letter ballot of the Association if a majority of the votes of the Corporate and Honorary Members present and voting is affirmative. Any proposal so submitted shall have the approval of the Association if a majority of the votes cast upon it by letter ballot is affirmative."

(This was agreed to by Mr. Gosline and his second.)

THE CHAIRMAN: It has been moved and seconded that the Report of the Committee on Preservatives recommending that the iodine-potassium ferricyanide-starch test be submitted by letter ballot. All in favor of that will please say "aye"; contrary "no"; it is so ordered.

There are some points in this report I would like to have some little discussion on. The first: if what this Committee says is true that there is some effect on the strength of wood by hot zinc chloride solutions, why do you use hot zinc chloride solutions in treating.

DR. A. L. KAMMERER: I do not understand that was the conclusion. Conclusion 3 refers to exposure to undue temperature after treatment. That is, if the treated wood is in the interior of a building exposed to temperatures considerably higher than ordinary room temperature in close proximity to a steam-pipe, for instance, there would be a marked decrease in strength, but I do not think it has any reference to the temperature of the solution during treatment.

THE CHAIRMAN: It has been a subject discussed many, many times, and I was afraid someone might get the impression from that report that was what was meant—that it was the hot solution used in treatment—and I was sure the report did not mean any such thing.

Then the question of sampling at point of shipment. Is it the understanding of the Committee that it is opposed to sampling fused zinc chloride at the point of shipment?

MR. L. C. DREFAHL: The Committee means that could be arranged for, if desired. The Committee believes that samples such as furnished any of those people who wanted samples of that kind would be one solution of the problem. If anyone wanted samples of zinc chloride taken at point of production those matters could be arranged for.

THE CHAIRMAN: This Committee, under "Conclusion," says:

> "While it is true that vertical-retort tar is a coal tar, and the oil made from it is a coal-tar creosote, this material cannot be accepted as standard creosote oil. It may be as good and even better, but its value as a preservative is as yet unknown. It must stand on its own merits, which can only be determined by actual use and service tests."

I would like to have that come up for discussion, whether it is the sense of the meeting that this should be embodied as a conclusion of the Preservatives Committee and admitted to the MANUAL.

MR. R. L. ALLARDYCE: We have used English creosote oil for a great many years, and we have had wide experience in regard to preservatives, and I do not see why we should take up another oil at the present time, not knowing what results we are going to have. We have worked a good many years with the oil we have been using, and now to go into something else would be merely a test proposition. The results we have obtained from the English oil are tests of 35 or 40 years' work.

THE CHAIRMAN: Any other remarks on this report?

MR. A. R. JOYCE: The Committee defines "vertical-retort tar" as a coal tar. Is that correct?

THE CHAIRMAN: They say it in the report.

MR. A. R. JOYCE: And they also define, or have previously defined "creosote oil" as a product of coal tar?

THE CHAIRMAN: I take it so.

MR. A. R. JOYCE: In their previous reports have they accepted creosote as a preservative?

THE CHAIRMAN: I wish the Preservatives Committee to be interrogated rather than me.

DR. A. L. KAMMERER: I think I can easily say "yes" to that; the Committee may not have, but I think everybody has.

MR. A. R. JOYCE: Is it not through the Service-Records Committee that the results of coal-tar creosote treatment are better known rather than through the Preservatives Committee?

DR. A. L. KAMMERER: Well, I guess that is true in recent years.

MR. A. R. JOYCE: That is the division that apparently arises in this "Conclusion"—the question as to why the Preservatives Committee, which heretofore has been more of a definitive committee, should suddenly assume the role of a service-records committee. I would like to have the Chairman explain the change in attitude.

DR. A. L. KAMMERER: The Committee really did not consider this point. The thought whether we were over-stepping our limits or not never occurred to us. If the convention feels that in providing for this service-test, and also in stating that the value of the vertical-tar is dependent on service-records, we have gone beyond the allotted boundaries of the Committee on Preservatives, I suppose that part should be eliminated from our report. The Committee did not realize that the limits of its activities were so sharply defined. To compile a lot of data and information about a new preservative and then refrain from offering a summary and conclusion is difficult and unsatisfactory, to say the least. However, we have no feeling in the matter one way or the other.

MR. WALTER BUEHLER: I feel that the Association as an Association owes something to the readers of its publications and the users of preserved wood. Now, if the Preservatives Committee has been instructed to make a report on preservatives, unless there is some other committee that will report on the merits of preservatives, it is certainly within the province of the Preservatives Committee to point out the relative values of the preservatives upon which it reports. Otherwise, we will have in our PROCEEDINGS reports of the Preservatives Committee on a number of preservatives, valuable or valueless, with no guide to the readers of the PROCEEDINGS as to the value of those preservatives, so if it is not within the province of the Preservatives Committee to point this out, there should certainly be another committee so this matter is taken care of in our publications.

MR. R. F. HOSFORD: I think I will have to join in the discussion, because I may get a call down in the morning for doing about the same thing. As I look at it the Committee found this thing that needed to be done and started ahead to do it. Now, of course, I think it is up to the Executive Committee to tell the various working committees just what they are to work on. It may be the decision of the Executive Committee next year that some other committee should follow service-tests, etc., of vertical-retort-tar creosote, but I believe the Preservatives Committee is to be commended and not blamed for starting it, and I move that the matter be referred to the Executive Committee for assignment.

MR. JOHN FOLEY: The Committee's report does not indicate that they wish to assume the job of looking up service-records. It merely states that none are available, and it may be assumed that the Committee on Service-Records will gather and present for the information of the Association and the Committee on Preservatives any data which may be procurable.

In saying that vertical-retort-tar creosote is a coal-tar creosote and yet questioning its acceptance now as a satisfactory wood-preserving oil, it seems to me that the Committee on Preservatives has assumed an illogical position. They decline to approve the oil merely because it fails to meet the arbitrary standards set by the Committee in connection with the specific gravities of certain fractions, about which there has been considerable discussion and no general agreement. There has been used with satisfactory results much imported oil that has not met the Committee's gravities, which do no more than indicate the character of the material from which the creosote has been obtained and do not indicate anything regarding its preservative properties.

THE CHAIRMAN: This conclusion is certainly something new in the line of Preservatives Committee reports, and it is just a question whether we want it understood or know whether we are going to adopt a policy of having the Preservatives Committee pass on preservatives. We, in this Association, are supposed to treat wood by preservatives, enabling us to get good service out of the timber treated. We are not here to promote one process or another. They are all excellent and can give good results no matter which one you use, and I dislike to see anything of this character creep into our work unless it is understood by all. I would like to have your opinion as to whether we should allow this conclusion to stand as a part of the Preservatives Report.

MR. G. M. HUNT: There is a paragraph in the report that seems to me might clarify things. It says:

> "Creosote oil made from vertical-retort tar on fractionation yields fractions which fall below the specific gravity requirements of the A. W.-P. A. specifications."

Well, that eliminates it then. They say on another page it cannot be accepted as standard creosote. They do not say whether it is a good or bad oil, they merely point out the fact that creosote oil does not satisfy our preservative specifications.

THE CHAIRMAN: Any other remarks on this question?

DR. A. L. KAMMERER: Might I say that if this paragraph seems to be offensive to anyone, rather than have it stand as it is, it can easily be modified so as to take out that element which is objectionable. As Mr. Hunt has just said, we specifically state that oil from vertical-retort tar does not comply with our standard specifications for creosote oil. I think, therefore, that the first part of the concluding paragraph could stand:

> "While it is true that vertical-retort tar is a coal tar, and the oil made from it is a coal-tar creosote, this material cannot be accepted as standard creosote oil."

I do not know just how to form a motion on this paragraph. I think the easiest way would be to omit the concluding paragraph entirely, simply ending with the table, if the Association so desires. The Committee desires to withdraw this paragraph. Personally, I do not feel that it offends any of our traditions.

MR. WALTER BUEHLER: It seems to me that it is up to the Executive Committee. The question is not in the hands of the Preservatives Committee, or a service-test committee, and as they placed it in the hands of the Preservatives Committee we should stand by the report of the Preservatives Committee. I question the advisability of the report going in without that conclusion.

THE CHAIRMAN: Has Dr. von Schrenk anything on this subject?

DR. HERMANN VON SCHRENK: Personally, I do not quite understand what this discussion is all about. I read this report through very carefully and I did not find any fault with its conclusions. Of course, I am not well versed in the rules and regulations of the Committees. They have simply said there are not any records available.

MR. E. T. HOWSON: It seems to me that question is merely one of jurisdiction, and that we should not spend much time discussing it. If it was a question of merit and conclusion, that is another matter. There is no duplication of records as I understand. The Committee has studied the subject, therefore, even if the Committee may have gotten out of the customary channel, if the information is correct and is valuable, the Association is indebted to the Committee for bringing it in.

THE CHAIRMAN: Will someone make a motion covering this situation now?

MR. E. T. HOWSON: I move the acceptance of the whole of the Committee's report as information.

MR. O. C. STEINMAYER: I second the motion.

MR. WALTER BUEHLER: Why is it necessary to make a separate motion as regards that particular part of the report? Mr. Gosline first made a motion to accept those two recommendations. He changed that, but he included in connection with that first motion that the report be accepted as information, and I understand his only change was to leave out this one recommendation as made.

THE CHAIRMAN: I did not so understand you. We will vote on that motion: that the iodine-potassium ferricyanide-starch test be adopted as standard and the balance of the report be accepted as information. All those in favor say "aye"; opposed, "no"; it is carried.

The Committee is excused with thanks.

THE CHAIRMAN: The next paper will be by Mr. R. G. Smith, of this city, on "Cresoil," a proposed wood preservative.

(Lantern slides are shown in connection with Mr. Smith's paper.)

CRESOIL.

By R. G. Smith.

Cresoil is the invention of J. C. Fitzsimmons, of San Francisco, California. It consists of a solution of mineral oil, preferably of an asphaltic base, and cresoil, or cresylic acid. For general use the solution should be in the proportion of 95% of mineral oil and 5% of cresylic acid by volume. In special cases the percentage of cresylic acid may be varied to meet the conditions of the case.

The oil should preferably be an asphaltic residuum oil of approximately 14° Baume gravity at 60° F., and the cresylic acid at least 95% pure.

The following tests were made to determine the suitability of Cresoil as a wood-preservative. The tests were made on Douglas fir at the St. Helens Creosoting Plant, St. Helens, Oregon, by the courtesy of the former manager, Mr. F. D. Beal:

(1) Stability of Cresoil.
(2) Penetration of Cresoil into the wood.
(3) Toxicity of Cresoil in comparison with creosote.
(4) Permanency of Cresoil in the wood.
(5) Toxicity of Cresoil taken from ties after evaporation.
(6) Service-tests of ties.
(7) Comparison of physical and chemical properties of creosote and Cresoil.

1.—Stability of Cresoil.

The purpose of these tests was to show that there was a thorough solution of the cresylic acid in the mineral oil, and that there would be no separation of the cresylic acid from the mineral oil in the treatment of wood, and 3 separate experiments were made to prove the stability of Cresoil.

I.—(a) To illustrate that Cresoil is a solution and not a mechanical mixture or an emulsion or a supersaturated solution of liquids and solids, the following microphotographs were taken:

(1) Of asphaltic oil and cresylic acid, showing a solution,
(2) Of 25% asphaltum and 75% tar, showing a mechanical mixture,
(3) Of oil and water, showing an emulsion,
(4) Of coal-tar creosote at 75° F., showing a supersaturated solution in which the crystals have formed in the liquid.

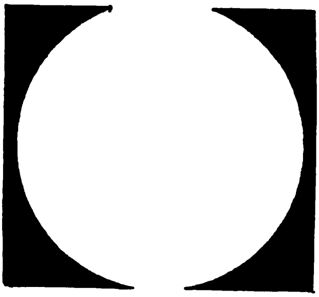


Fig. 1.—A Microphotograph of Asphaltic Oil and Cresylic Acid, Showing a True Solution.
(Magnification of 75 diameters.)

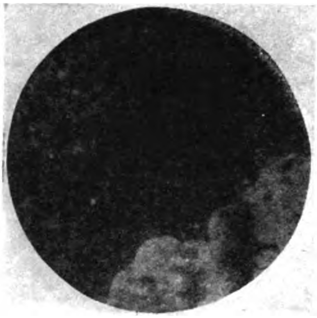


Fig. 2.—A Microphotograph of 25% Asphaltum and 75% Tar, Showing a Mechanical Mixture.
(Magnification of 75 diameters.)

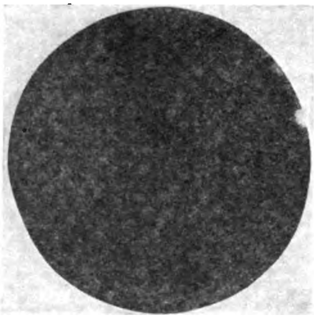


Fig. 3.—A Microphotograph of Asphaltic Oil and Water, Showing an Emulsion.
(Magnification of 75 diameters.)

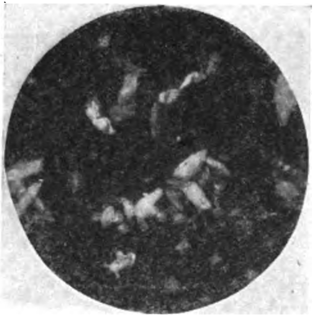


Fig. 4.—A Microphotograph of Coal-Tar Creosote at 75° F., Showing a Supersaturated Solution in Which the Crystals Have Formed in the Liquid.
(Magnification of 75 diameters.)

The next experiment to show the stability of Cresoil was made in the following manner:

I.—(b) During a series of treatments a sample of Cresoil was taken before and after each treatment, and during a series of 7 treatments without any additions of oil or Cresoil, the following was the percentage of cresylic acid by analysis in these samples:

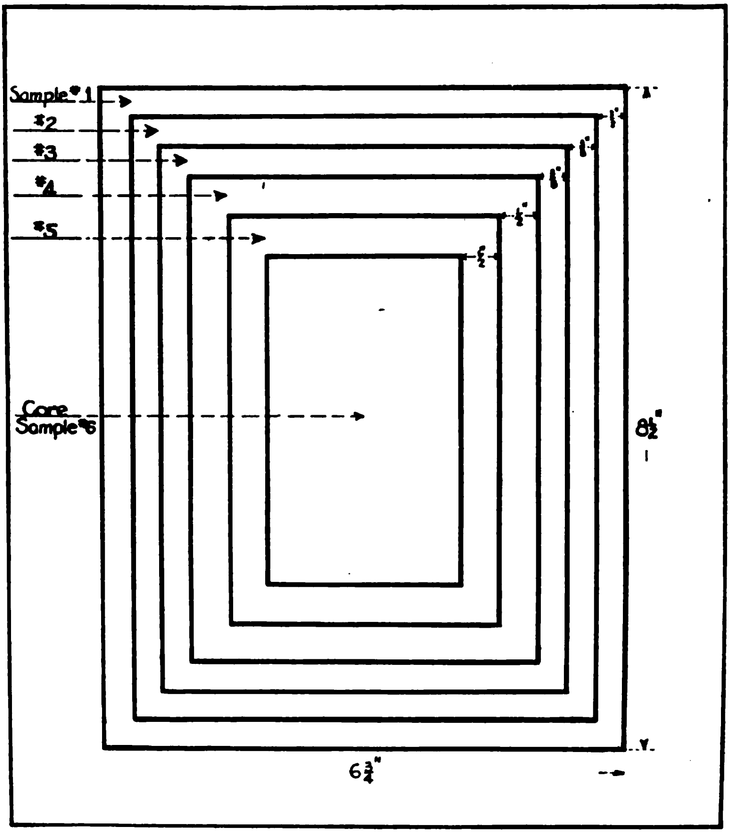


Fig. 5.—Sections of Treated Cross-Tie From Which Cresoil was Extracted to Determine Stability of the Solution.

Sample No.	Per cent.
1	5.1
2	5.5
3	5.2
4	5.4
5	5.4
6	5.4
7	5.4

It will thus be seen that the mixture remains stable after being continually heated under vacuum, and drawn into wood and forced out again.

I.—(c) The next test on the stability of the solution of Cresoil was made by extracting the Cresoil from the different sections of a treated tie, and obtaining the percentage of cresylic acid in the solution after the extraction from different sections. The samples were made by taking a section parallel to the sides of the tie, as indicated in Fig. 5.

Sample Number.	Location in Tie.	Cresoil Lbs. per Cu. Ft. in Wood	Cresylic Acid in Extracted Oils.
1	External ring ⅜ inch	39.6	5.07
2	⅜ inch off above, remaining	26.9	4.9
3	⅜ " " " "	8.8	5.1
4	⅜ " " " "	6.75	5.1
5	⅛ " " " "	1.24	No petroleum oils or cresylic acid

CONCLUSION —It will be seen from these tests that there has been no separation of the asphaltic oil and the cresylic acid, for it is seen that the percentage of cresylic acid is constant throughout the sections, and that in section 5 there is neither an asphaltic petroleum oil nor a cresylic acid, which shows there is no separation or filtering action of the wood on Cresoil. It will also be seen that the oil penetrated 1⅝ inches, and due to the rebound, most of the oil was retained in the outer ¾ inch, giving a full-cell process for the outer rings.

2.—Penetration of Cresoil Into the Wood.

The method of treatment as developed by Mr. Beal in St. Helens gave good penetrations into Douglas fir by Cresoil. This method of treatment was only slightly different from the ordinary creosote treatment, in that the gross absorption allowed in the tie was much greater than with creosote, as the "rebound" was also much greater than with creosote.

For instance, gross absorption of 22 lbs. to 25 lbs. would rebound to 7 lbs. to 9 lbs. net absorption.

Under this method of treatment, Cresoil readily penetrated into the wood from 1½ inches to 1¾ inches in depth.

The following illustrations will show this penetration:

At the present time, however, this question of penetration and equal distribution is being solved on the Pacific Coast by the perfection of the new process of perforating Douglas fir.

The following table will show that Cresoil is more readily injected into wood than creosote:

CROSS-TIES.

Treatment.	Hours Under Pressure.	Gross Absorption per Cu. Ft.
Creosote (full-cell)	7	12.70
Cresoil "	4	21.33
" "	7	22.41
" "	8	24.61

WOOD-BLOCKS.

Treatment.	Hours Under Pressure.	Net Absorption per Cu. Ft.
Creosote (full-cell)	6	14
Cresoil "	2¼	17

CONCLUSION.—From the above tests it will be seen that Cresoil can be injected into wood (Douglas fir) satisfactorily, and more easily than creosote.

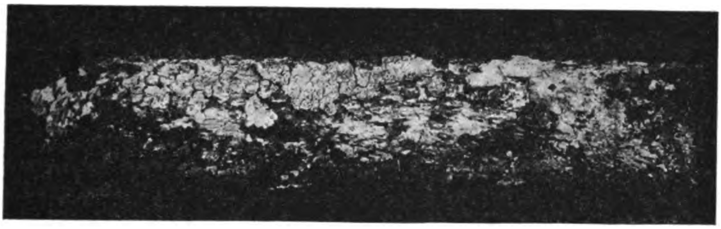


Fig. 8.—Piece of Buckeye From Which the Cultures Were Obtained for Toxicity Tests.

3.—Toxicity of Cresoil in Comparison With Creosote.

The toxic-tests were carried out, first on mixtures of fungi and molds, and then on a definite wood-destroying fungi.

The first test was carried out on mixtures of fungi and molds, obtained from pieces of infected buckeye and live oak. The piece of buckeye was very light in weight, bleached white, and had lost all appearance of grain or texture. It was covered on the outside with a species known as oyster fungi, *Lentinus Lepidus.* The piece of live oak was taken from the heart of a decayed oak stump, and was very easily disintegrated.

Fig. 8 shows the piece of buckeye from which the culture was obtained in toxicity test.

The gelatine for this test was made by dissolving 2% of agar-agar, 2% of beef extract, and 2% of malt extract in boiling water.

Cresoil was compared with Grade "A" creosote, the result being as follows:

	Killing Point. Per cent.	Preservative per Cu. Ft. of Wood Necessary to Kill Fungi. Lbs.
Cresoil, 5% solution	4	2.5
Creosote, Grade "A"	9	5.6

The second toxicity test was made on a culture of *Fomes Annosus* obtained from Mr. C. J. Humphreys of the Forest Products Laboratory at Madison, Wisconsin. The following are the results:

	Killing Point.	Preservative per Cu. Ft. of Wood Necessary to Kill Fungi.
	Per cent.	Lb.
Cresoil, 5% solution	1.2	0.75
Creosote, Grade "A"	0.35	0.22

From the above tests it will be seen that in one case Cresoil was more toxic than creosote, and in the other case creosote was more toxic than Cresoil, though in both cases Cresoil was toxic enough for all practical purposes.

4.—Permanency of Cresoil in the Wood.

Two tests were made for permanency of Cresoil in the wood, one where the cross-ties were heated artificially, and the other where determinations were made on the ties after a service-test in the track.

Two ties treated with Cresoil, 5% solution, were taken from the same charge. The Cresoil was extracted immediately from the various sections of wood as previously noted in this report, and the other tie was placed above the treating retorts of the St. Helens Creosoting Plant. A tie treated with creosote also was placed above the treating retorts for comparison.

The loss by weight was as follows: The tie treated with Cresoil lost 5 lbs. by weight in 240 days, and was constant for at least 90 days. The tie treated with creosote lost 9 lbs. in 155 days, and 11¾ lbs. in 360 days, losing ¼ lb. in the last 60 days.

Both ties were then sawed up in the same number of sections as previously noted in the report, and the following are the results:

CROSS-TIE TREATED WITH CRESOIL.

Sample Number.	Location in Tie.	Cresoil Lbs. per Cu. Ft. in Wood.	Cresylic Acid in Extracted Oils.
1	External ring ⅜ inch	27.2	1.80
2	⅜ inch off above, remaining	21.4	1.58
3	⅜ " " " "	17.2	1.62
4	⅜ " " " "	5.7	1.57
5	½ " " " "	3.4	trace

NOTE.—Later experiments showed more accurate methods of obtaining the cresylic acid in Cresoil, and these figures would be increased 0.5%.

CROSS-TIE TREATED WITH CREOSOTE.

Sample Number.	Location in Tie.	Creosote Lbs. per Cu. Ft. in Wood.
1	External ring ⅜ inch	23.4
2	⅜ inch off above, remaining	20.0
3	⅜ " " " "	16.1
4	⅜ " " " "	5.5

The distillation of the creosote before and after evaporation of the creosoted tie is as follows:

Fraction Number.	Range.	Before Evaporation. Per cent.	After Evaporation. Per cent.
1	Up to 205° C.	4.2	0.5
2	205–245° C.	24.2	17.0
3	245–270° C.	9.2	16.0
4	270–320° C.	17.4	23.6
	320–340° C.	18.1	----
	Residue at 240° C.	22.5	----
	320–450° C.	----	21.7
	Residue at 450° C.	----	21.2

It will be noted that creosote has lost most of the highly toxic agents, such as tar acids.

CONCLUSION.—The loss due to evaporation with Cresoil is shown to be less than one half the amount with creosote.

5.—Toxicity of Cresoil Taken From Ties After Evaporation.

After the preservatives had been taken from the cross-ties that had been evaporated down to constant weight, toxic-tests were made on these preservatives, and it was found that approximately 3 times as much of each of the preservatives was needed to kill the fungi used in the previous toxic experiments, the results being as follows:

FUNGI FROM ROTTING WOOD.

	Killing Point	Preservative Per Cu. Ft.	Preservative per Cu. Ft. to Each Section as Shown in Fig. 3.				
			(1)	(2)	(3)	(4)	(5)
	Per cent.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Cresoil	12	7.5	27.2	21.4	17.2	5.7	3.4
Creosote	23	14.3	23.4	20.0	16.1	5.5	----

CULTURE OF FOMES ANNOSUS.

	Killing Point.	Preservative Per Cu. Ft.	Preservative per Cu. Ft. to Each Section as Shown in Fig. 3.				
			(1)	(2)	(3)	(4)	(5)
	Per cent.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Cresoil	4.0	2.2	27.2	21.4	17.2	5.7	3.4
Creosote	0.9	0.56	23.4	20.0	16.1	5.5	----

It will thus be seen that even under the worst possible conditions of the fungi from the rotting wood, there is sufficient Cresoil and creosote in the first 3 sections to kill all fungi, so that the fungi could not penetrate into the heart of the wood. In the toxic-tests on the culture of *Fomes Annosus*, it would be seen that there is sufficient Cresoil and creosote in the first 4 sections to kill the culture.

It will be noted that after evaporation has taken place, Cresoil with 5% solution of cresylic acid is comparable in every way to creosote, and the advantage of the Cresoil is that the toxicity can be increased to any amount necessary to suit the condition. It will be noted also that the loss in toxic properties is in the same ratio.

6.—Service-Tests of Cross-Ties.

In the second test on the permanency of Cresoil in the wood, 2 ties were taken after service in the tracks of the Chicago, Milwaukee & St. Paul, and Spokane, Portland & Seattle Railroads, respectively.

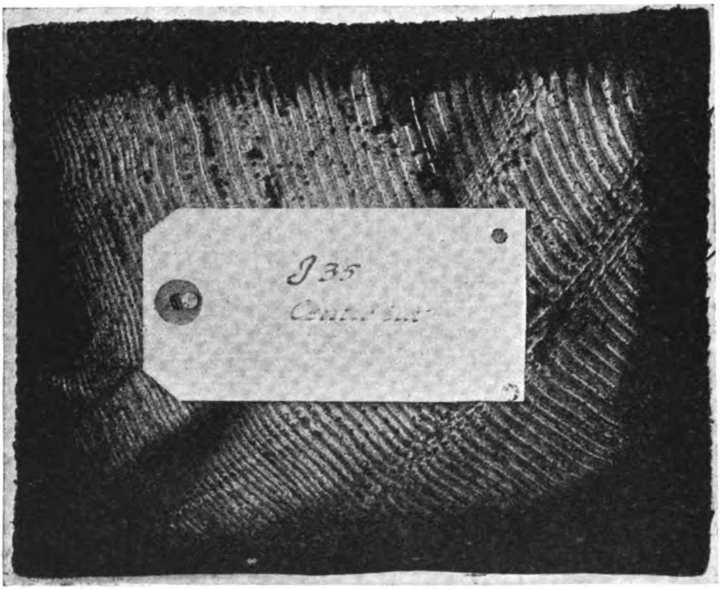


Fig. 6.—Cresoil 5% Mixturre. Green Douglas-Fir Tie. Gross Absorption, 22.4 Lbs. Per Cubic Foot. Net Absorption. 7 Lbs. Per Cubic Foot.

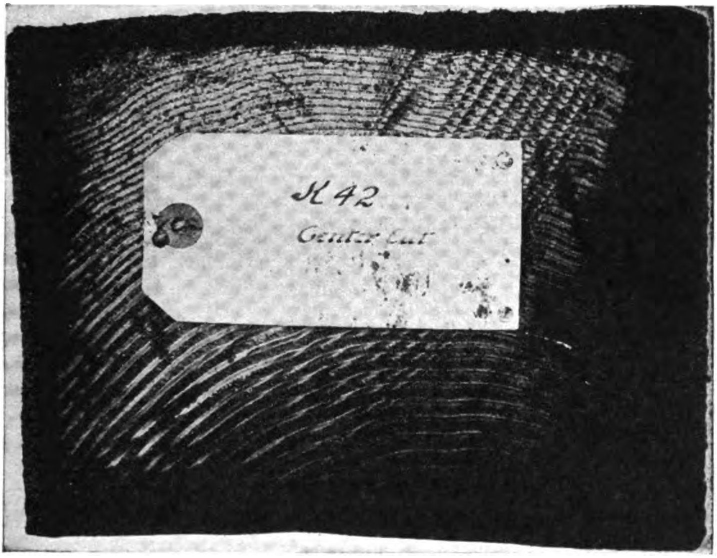


Fig. 7.—Cresoil 5% Mixture. Green Douglas-Fir Tie. Gross Absorption, 21.98 Lbs. Per Cubic Foot. Net Absorption, 9.15 Lbs. Per Cubic Foot.

CHICAGO, MILWAUKEE & ST. PAUL RAILROAD.—In 1915 railroad ties treated with 5% solution of Cresoil were supplied to the Chicago, Milwaukee & St. Paul Railroad. Mr. J. F. Pinson, District Engineer at Seattle, Wash., stated that "these ties were placed in the track 4 miles west of Lind, Wash., in what is known as a semi-arid portion of the State. During the summer time it is very dry and hot in that section, and during the winter there is some rainfall, though not excessive. The soil is mostly volcanic ash, and we find that untreated timber decays very rapidly, and will last ordinarily not to exceed 8 years."

A tie marked "M-52" was taken from this track, and received on January 3, 1919, in good condition, showing no signs of decay. The object of the examination was to determine the percentage of cresylic acid left in the Cresoil, and to determine the toxic value of the preservative left in the tie.

The ties were sawed in half. Several cross-sections were cut off each tie, and part of the ties sawed up in order to get them into sawdust so that the preservative could be extracted.

The percentage of the cresoils left in the tie averaged 2.43%.

The toxic properties were measured against *Fomes Annosus*, samples of which were received from the Forest Products Laboratory at Madison, Wisconsin.

The following shows comparison of toxic properties of the original solution and the solution left in the tie:

	Killing Point. Per cent.	Preservative per Cu. Ft. of Wood Necessary to Kill Fungi. Lbs.
Cresoil, 5% solution	1.2	0.75
Preservative left in tie, 2.48% solution Cresoil	4.1	2.6

SPOKANE, PORTLAND & SEATTLE RAILROAD.—Ties were supplied at the same time, in 1915, to the Spokane, Portland & Seattle Railroad, being treated with a 5% solution of Cresoil. In a letter from Mr. E. E. Lilley, Assistant General Manager at Portland, Oregon, he stated that these ties were placed in a track approximately 300 feet east from Mile Post 105, that the track is ballasted, and subject to a continuous covering of blow-sand, owing to the surrounding conditions and prevailing wind.

The district has a very hot summer and varying dry winter weather, with freezing an exception.

The Superintendent of Maintenance of Way stated that 5 years would reduce an untreated 7x9 tie to such a condition as to make its use of no value in the support of the track.

The ties under consideration were put in the track at a point where the life of a tie was as short as anywhere in the district.

A tie marked "No. 18 A-2" was received about January 1, 1919, taken from this set of ties, and it was in splendid condition, with no signs of decay.

The percentage of cresoils left in the tie averaged 2.23%.

The toxic properties were measured against *Fomes Annosus*, and the following table shows the comparison of the toxic properties of the original solution, and the solution left in the tie:

	Killing Point. Per cent.	Preservative per Cu. Ft. of Wood Necessary to Kill Fungi. Lbs.
Cresoil, 5% solution	1.2	0.75
Preservative left in tie, 2.23% solution Cresoil	4.8	3.0

The following would be the approximate amounts of preservative per cubic foot in the sections of a tie, beginning from the outside.

Section No.	Inch.	Approximate Pounds.
1	⅜	25
2	⅜	20
3	⅜	15
4	½	5

It will thus be seen that the toxic value of the Cresoil in the tie after having been in service approximately 4 years has still a very wide margin, or factor of safety, in toxic value.

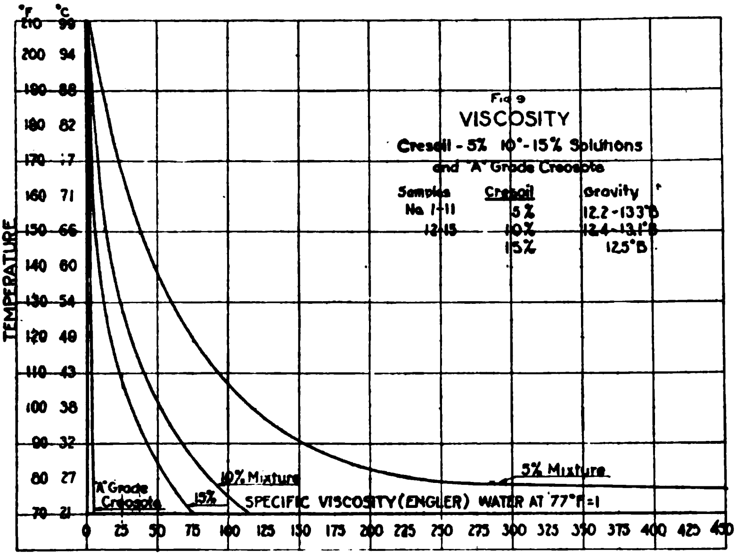
7.—Comparison of Physical and Chemical Properties of Creosote and Cresoil.

VISCOSITY.—Fig. 9 shows the viscosity temperature curves of Grade "A" creosote and Cresoil. The viscosity in Englers is as follows:

	Temperature 70° F.	Temperature 200° F.
Creosote	5	1.5
Cresoil, 5% solution	500	5.0

It will be seen that at ordinary temperatures Cresoil, 5% solution, is many times more viscuous than Grade "A" creosote, and for this reason will not bleed, but will remain solid in place.

At treating temperatures of approximately 200° F., the viscosity of Cresoil approaches closely that of creosote which makes it easier workable at treating temperatures.



SPECIFIC GRAVITY.—The specific gravity or weight per cubic foot is much less with Cresoil than with coal-tar creosote, so with specifications calling for pounds per cubic foot, the volume of oil injected into the wood is about 14% greater.

	Specific Gravity at 70° F.	Specific Gravity at 200° F.
Creosote	1.075	1.011
Cresoil, 5% solution	0.9790=18° Be.	0.9440=18° Be.

COEFFICIENT OF EXPANSION.—The coefficient of expansion is approximately 15% less with Cresoil than with coal-tar creosote, which would make it less liable to bleed in hot weather. The coefficient of expansion of creosote is .00044, and of Cresoil, 5% solution, is .00038.

SURFACE TENSION—The surface tension taken by the drop weight method is as follows:

Temperature. Degrees F.	Dynes per Centimeter. Creosote.	Cresoil.
70	39.84	36.54
120	37.78	30.77
200	37.40	27.49

The physical and chemical characteristics of Cresoil and creosote are shown in the analytical diagram, Fig. 10.

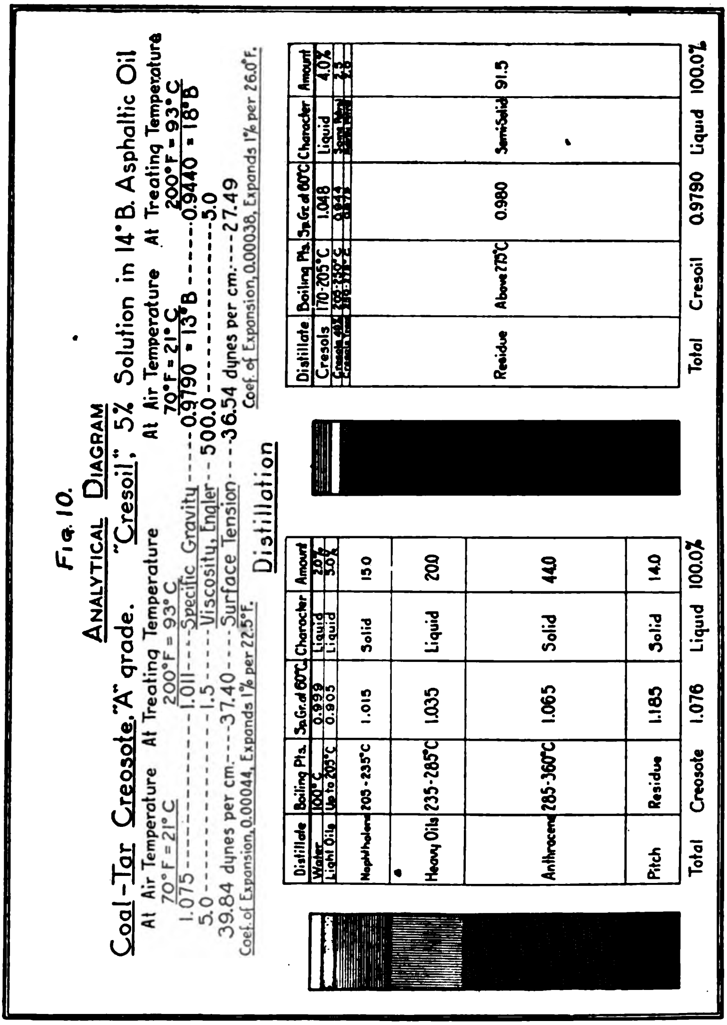


Fig. 10.

ANALYTICAL DIAGRAM

Coal-Tar Creosote, "A" grade. At Air Temperature 70°F = 21°C	At Treating Temperature 200°F = 93°C		"Cresoil," 5% Solution in 14° B. Asphaltic Oil At Air Temperature 70°F = 21°C	At Treating Temperature 200°F = 93°C
1.075	1.011	Specific Gravity	0.9790 = 13°B	0.9440 = 18°B
5.0	1.5	Viscosity, Engler	500.0	5.0
39.84 dynes per cm.	37.40	Surface Tension	36.54 dynes per cm.	27.49

Coef. of Expansion, 0.00044, Expands 1% per 22.5°F.

Coef. of Expansion, 0.00038, Expands 1% per 26.0°F.

Distillation

Distillate	Boiling Pts.	Sp. Gr. at 60°C	Character	Amount
Water	100°C	0.999	Liquid	2.0%
Light Oils	Up to 205°C	0.905	Liquid	3.0%
Naphthalene	205-235°C	1.015	Solid	15.0
Heavy Oils	235-285°C	1.035	Liquid	20.0
Anthracene	285-360°C	1.065	Solid	44.0
Pitch	Residue	1.185	Solid	14.0
Total Creosote		1.076	Liquid	100.0%

Distillate	Boiling Pts.	Sp. Gr. at 60°C	Character	Amount
Cresols	170-205°C	1.048	Liquid	4.0%
[illegible]	205-250°C	0.944	[illegible]	2.5
[illegible]	[illegible]	0.978	[illegible]	2.0
Residue	Above 275°C	0.980	Semi-Solid	91.5
Total Cresoil		0.9790	Liquid	100.0%

General Summary of Conclusions.

We believe that the following points have been conclusively proved:

(1) That Cresoil is a stable solution, which does not separate in the treatment of wood, or in the wood itself.

(2) That Cresoil can be readily injected into the most refractive woods, such as Douglas fir.

(3) That the toxicity of the 5% solution compares favorably with creosote, and is sufficient for all practical purposes.

(4) That Cresoil does not evaporate from the wood as readily as creosote, and loses its toxic values slowly, about in the same ratio as creosote.

From this general summary of conclusions, Cresoil should make as equally favorable a wood-preservative as creosote.

THE CHAIRMAN: Gentlemen, you have heard Mr. Smith's able article on cresoil. Are there any questions on this paper at this time?

MR. R. F. HOSFORD: I would like to ask a question about the number of ties placed in these two cases: what is the history of the other ties which were placed?

MR. R. G. SMITH: I think there were about—I am not quite sure, the St. Helens people have the record—25 ties. There was an experimental lot sent to both railroads.

MR. R. F. HOSFORD: What is the history of the rest of them?

MR. R. G. SMITH: We asked them to pick out a sample tie. They picked out the tie to send us to see how much of the preservative was left. We have no history of the rest of them; they were all placed together, and the tie was supposed to be a representative sample. The history could be obtained straight from the railroad.

MR. A. A. BROWN: I would like to ask whether there were any service-tests in the use of cresoil in treated piles.

MR. R. G. SMITH: I believe Mr. Nicholson in Seattle arranged for a test on Puget Sound this year. Mr. Nicholson is Port Engineer of Seattle.

THE CHAIRMAN: Any other questions to be asked of Mr. Smith? Our time is limited and we must hurry on with our program.

We will thank Mr. Smith for his paper and turn to the next subject, which will be the Report of Sub-Committee No. 7-1 on Track. Mr. Cooper is Chairman of this Sub-Committee, and we ask that he make his report at this time.

(Mr. Joyce resumes the Chair.)

REPORT OF SUB-COMMITTEE NO. 7-1—TRACK

To the Members of the American Wood-Preservers' Association:

In handing this report your Committee would call attention to the reports submitted by the Chicago, Rock Island & Pacific Railway Company, St. Louis-San Francisco Railway Company, Baltimore & Ohio Railroad Company, Santa Fe System, and the Chicago, Indianapolis & Louisville Railway which are made up from test sections, and your Committee would recommend that this manner of making up reports be followed in the future by all railroads submitting reports.

Your Committee feels that in adopting this method much more reliable data are obtained, for the reason that a record of each particular tie in these sections is kept, and, furthermore, a close supervision is kept over these sections, enabling those responsible to keep a close supervision both in tie renewals and tie removals.

Your Committee also feels that it is a distinct advantage in reporting to keep each class of wood used in these sections separately, as by so doing the average life of each kind of wood may be easily determined.

While it is possible that the form used might be improved upon, your Committee would suggest that next year the Committee appointed be instructed to follow up this question with the view of having this form, or one similar, adopted by all roads as standard, which, in the opinion of your Committee, would result in making the reports of more value to all concerned.

On account of there having been no material change in the test-records as published and provided by the Forest Products Laboratory at Madison, and on account of the expense of printing same, your Committee has decided that it will not go to the expense this year, it being understood that the records will be kept up in good shape, and if there are any material changes by next year they will be published.

S. D. COOPER, *Chairman*,
G. C. DIXON,
C. F. FORD,
O. C. STEINMAYER,
EARL STIMSON,
T. G. STULL.

SPECIAL CROSS-TIE TESTS ON THE SANTA FE SYSTEM.

Station or Line	Kind of Wood	Treatment	Location	
			M.P. and Feet	to M.P. and Feet
Marceline, Mo	Hewn Pine	Rueping	348 - 2506	348 - 2838
Sutton, Kans	Hewn Pine	Rueping	436 - 2600	
Ponca City, Okla	Hewn Pine	Rueping	286 - 4754	
Bliss, Okla	Sawn Pine	Rueping	297 - 245	
Perry, Okla	Hewn Pine	Rueping	323 - 5274	
Perry, Okla	Sawn Pine	Rueping	323 - 5274	
Garnett, Kans	Sawn Pine	Rueping	86 - 435	
Argonia, Kans	Sawn Pine	Rueping	264 - 1580	
Hutchinson Cutoff	Sawn Gum	Rueping	219 - 0	
Hutchinson Main Line	Sawn Gum	Rueping	219 - 1150	
Plevna, Kans	Sawn Gum	Rueping	240 - 3696	
Plevna, Kans	Sawn R.Oak	Rueping	240 - 3696	
Ottawa Cutoff	Hewn Pine	Rueping	80 - 0	87 - 3155
Smithshire, Ill	Sawn Beech	Rueping	201 - 2640	
Marceline, Mo	Sawn Beech	Rueping	349 - 1820	
Tecumseh, Kans	Sawn Beech	Rueping	47 - 4980	
Newton, Kans	Sawn Beech	Rueping	181 - 2640	
Newton, Kans	Hewn Pine	Rueping	183 - 2640	
Newton, Kans	Sawn Pine	Rueping	188 - 2640	
Newton, Kans	Hewn R.Oak	Rueping	188 - 2640	
Newton, Kans	Sawn Gum	Rueping	188 - 2640	
Hutchinson Cutoff	Hewn Pine	Rueping	247 - 1608	268 - 0
Hutchinson Cutoff	Sawn Pine	Rueping	247 - 1608	
Hutchinson Cutoff	Hewn Gum	Rueping	247 - 1608	
Hutchinson Cutoff	Hewn Ohia	Untreated	257 - 0	258 - 0
Hutchinson Cutoff	Sawn Ohia	Untreated	257 - 0	258 - 0
Hutchinson Cutoff	Hewn Pine	Rueping	290 - 0	294 - 1320
Newton, Kans	Hewn Pine	Burnett	179 - 264	184 - 3036
Newton, Kans	Hewn Pine	Burnett	179 - 264	184 - 3036
Newton, Kans	Sawn Pine	Burnett	179 264	184 - 3036
Walton, Kans	Hewn Pine	Rueping	173 - 0	178 - 1820
Newton, Kans	Sawn Pine	Burnett	179 - 264	184 - 3036
Walton, Kans	Sawn Pine	Rueping	173 - 0	178 - 1820
Walton, Kans	Hewn Oak	Rueping	173 - 0	178 - 1320
Turner-Holliday	Hewn Pine	Burnett	7 - 0	18 - 0
Turner-Holliday	Sawn Pine	Burnett	7 - 0	12 -
Turner-Holliday	Hewn Pine	Rueping	7 - 0	18 - 0
Turner-Holliday	Sawn Pine	Rueping	7 - 0	9 - 0
Turner-Holliday	Hewn Oak	Rueping	7 - 0	10 - 0
Clements, Kans	Hewn Pine	Rueping	800	

SPECIAL CROSS-TIE TESTS ON THE SANTA FE SYSTEM (Continued).

Station or Line	Number Originally Inserted	Date Inserted	Now in Track	Number Removed—Rotten					
				1915	1916	1917	1918	1919	1920
Marceline, Mo......	304	1905	134	8	....	....	....	....	....
Sutton, Kans........	44	1905	0	....	....	....	....	....	....
Ponca City, Okla....	190	1904	181	....	....	....	....	....	....
Bliss, Okla..........	275	1904	237	....	....	....	....	1	5
Perry, Okla..........	27	1904	27	....	....	....	....	....	....
Perry, Okla..........	366	1904	359	....	....	....	3	....	....
Garnett, Kans......	384	1905	300	26	12	22	....	....	....
Argonia, Kans......	372	1905	330	....	4	20	....	....	....
Hutchinson Cutoff...	390	1907	375	....	4	1	....	....	....
Hutchinson Main Line	230	1907	214	....	....	....	....	....	....
Plevna, Kans........	262	1907	245	....	....	....	....	....	....
Plevna, Kans........	52	1907	41	....	....	....	....	....	....
Ottawa Cutoff......	24238	1906	23881	....	....	....	....	....	3
Smithshire, Ill......	384	1912	379	....	....	....	....	....	....
Marceline, Mo......	99	1912	99	....	....	....	....	....	....
Tecumseh, Kans....	160	1912	160	....	....	....	....	....	....
Newton, Kans......	151	1912	151	....	....	....	....	....	....
Newton, Kans......	149	1913	149	....	....	....	....	....	....
Newton, Kans......	151	1913	151	....	....	....	....	....	....
Newton, Kans......	150	1913	149	....	....	....	....	....	....
Newton, Kans......	150	1913	150	....	....	....	....	....	....
Hutchinson Cutoff...	41021	1910	40823	....	....	....	....	....	....
Hutchinson Cutoff...	9436	1910	9206	....	....	....	....	....	....
Hutchinson Cutoff...	14497	1910	14495	....	....	....	....	....	....
Hutchinson Cutoff...	132	1910	132	....	....	....	....	....	....
Hutchinson Cutoff...	108	1910	106	....	....	....	....	....	....
Hutchinson Cutoff...	13600	1910	13592	....	....	....	....	....	....
Newton, Kans......	6357	1904	14	2257	219	540	1904	....	....
Newton, Kans......	9251	1905	1780	2246	572	434	140	3092	....
Newton, Kans......	2517	1904	124	1054	349	86	175	117	....
Walton, Kans.......	10994	1917	10994	....	....	....	....	....	....
Newton, Kans......	40	1905	2	....	16	6	13	....	....
Walton, Kans.......	1394	1917	1394	....	....	....	....	....	....
Walton, Kans.......	4395	1917	4395	....	....	....	....	....	....
Turner-Holliday.....	4640	1918	4640	....	....	....	....	....	....
Turner-Holliday.....	686	1918	686	....	....	....	....	....	....
Turner-Holliday.....	8794	1918	8712	....	....	....	....	....	1
Turner-Holliday.....	456	1918	456	....	....	....	....	....	....
Turner-Holliday.....	2864	1918	2864	....	....	....	....	....	....
Clements, Kans.....	165	1904	156	....	....	....	....	....	....

SPECIAL CROSS-TIE TESTS ON THE SANTA FE SYSTEM (Continued).

Station or Line	Number Removed									
	Mechanical Wear						Experimental Purposes			
	1915	1916	1917	1918	1919	1920	1915	1917	1919	1920
Marceline, Mo	12	6	15	.....	27	10	2	.....	.....	.....
Sutton, Kans	4	.....	1	17	.....	22	.....	.....	.....	.....
Ponca City, Okla	6	.....	.....	.....	.....	.....	2	1	.....	.....
Bliss, Okla	6	5	2	.....	8	.....	.....	.....	.....	.....
Perry, Okla	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Perry, Okla	.....	.....	.....	3	.....	.....	.....	.....	1	.....
Garnett, Kans	.....	.....	12	.....	.....	10	2	.....	.....	.....
Argonia, Kans	56	4	98	.....	.....	.....	.....	.....	.....	.....
Hutchinson Cutoff	.....	6	.....	.....	.....	.....	.....	.....	.....	.....
Hutchinson Main Line	.....	.....	.....	.....	16	.....	.....	.....	.....	.....
Plevna, Kans	.....	3	1	.....	.....	.....	.....	.....	.....	.....
Plevna, Kans	.....	.....	1	.....	.....	.....	.....	.....	.....	.....
Ottawa Cutoff	.....	.....	16	.....	.....	.....	.....	.....	.....	.....
Smithshire, Ill	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Marceline, Mo	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Tecumseh, Kans	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Newton, Kans	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Newton, Kans	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Newton, Kans	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Newton, Kans	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Newton, Kans	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Hutchinson Cutoff	.....	6	32	.....	4	.....	.....	.....	.....	.....
Hutchinson Cutoff	.....	.....	9	.....	.....	.....	.....	.....	.....	.....
Hutchinson Cutoff	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Hutchinson Cutoff	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Hutchinson Cutoff	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Newton, Kans	.....	.....	.....	.....	.....	1423	.....	.....	.....	.....
Newton, Kans	601	.....	.....	.....	.....	136	.....	.....	.....	.....
Newton, Kans	.....	.....	.....	.....	.....	612	.....	.....	.....	.....
Walton, Kans	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Newton, Kans	.....	.....	.....	.....	.....	3	.....	.....	.....	.....
Walton, Kans	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Walton, Kans	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Turner-Holliday	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Turner-Holliday	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Turner-Holliday	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Turner-Holliday	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Turner-Holliday	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Clements, Kans	.....	5	.....	.....	.....	.....	.....	.....	.....	.....

SPECIAL CROSS-TIE TESTS ON THE SANTA FE SYSTEM (Continued).

Station or Line	Number Removed—Other Causes						Date Last Inspection	Kind of Ballast
	1915	1917	1918	1919	1920	Total		
Marceline, Mo	90					170	9-23-20	Gravel
Sutton, Kans						44	9-30-20	Slag
Ponca City, Okla						9	9-29-20	Rock
Bliss, Okla					11	88	9-29-20	Rock
Perry, Okla						0	9-30-20	Rock
Perry, Okla						7	9-30-20	Rock
Garnett, Kans						84	10- 6-20	Rock
Argonia, Kans		60				242	10- 1-20	Rock
Hutchinson Cutoff					4	15	9-22-20	Rock
Hutchinson Main Line						16	9-22-20	Cinder
Plevna, Kans					13	17	9-22-20	Rock
Plevna, Kans					10	11	9-22-20	Rock
Ottawa Cutoff	7	8	8		315	357	9-28-20	Rock
Smithshire, Ill				1	4	5	9-24-20	Gravel
Marceline, Mo						0	9-23-20	Gravel
Tecumseh, Kans						0	9-22-20	Rock
Newton, Kans						0	9-28-20	Rock
Newton, Kans						0	9-28-20	Rock
Newton, Kans						0	9-28-20	Rock
Newton, Kans					1	1	9-28-20	Rock
Newton, Kans						0	9-28-20	Rock
Hutchinson Cutoff	75	*8	†72		1	198	9-23-20	Rock
Hutchinson Cutoff				221		280	9-23-20	Rock
Hutchinson Cutoff					2	2	9-23-20	Rock
Hutchinson Cutoff						0	9-23-20	Rock
Hutchinson Cutoff			2			2	9-25-20	Rock
Hutchinson Cutoff			6		2	8	9-27-20	Rock
Newton, Kans						6348	9-28-20	Rock
Newton, Kans			50			7471	9-28-20	Rock
Newton, Kans						2393	9-28-20	Rock
Walton, Kans						0	9-29-20	Rock
Newton, Kans						38	9-28-20	Screenings
Walton, Kans						0	9-29-20	Screenings
Walton, Kans						0	9-29-20	Screenings
Turner-Holliday						0	10- 4-20	Cinder
Turner-Holliday						0	10- 4-20	Rock
Turner-Holliday					81	82	10- 4-20	Rock
Turner-Holliday						0	10- 4-20	Rock
Turner-Holliday						0	10- 4-20	Rock
Clements, Kans						9	10- 5-20	Rock

* 70 removed account changing switch.

† 8 burned.

SPECIAL CROSS-TIE TESTS ON THE SANTA FE SYSTEM (Continued).

Station or Line	Wght. of Rail	Size of Tie-Plate	Ties per Mile	Kind of Spike	Tons Traffic per Annum	Sea-son-ing	Int. Ins.	Vac. Time Min.
Marceline, Mo........	85	6 x8-7½x9	3200	Cut	10,369,895	Air	......	......
Sutton, Kans.........	85	6 x8-7½x9	3200	Cut	6,499,249	Air	......	......
Ponca City, Okla......	90	7½x9	3200	Cut	2,550,296	Air	......	......
Bliss, Okla............	90	7½x9	3200	Cut	2,550,296	Air	......	......
Perry, Okla...........	90	7½x9	3200	Cut	2,550,296	Air	......	......
Perry, Okla...........	90	7½x9	3200	Cut	2,550,296	Air	......	......
Garnett, Kans.........	90	7½x9	3200	Cut	4,821,390	Air	......	......
Argonia, Kans.........	90	7½x9	3200	Cut	5,131,506	Air	......	......
Hutchinson Cutoff....	90	7½x9	3200	Cut	4,904,181	Air	......	......
Hutchinson Main Line	85	7½x9	3200	Cut	3,008,686	Air	......	......
Plevna, Kans.........	90	7½x9	3200	Cut	4,904,161	Air	......	......
Plevna, Kans.........	90	7½x9	3200	Cut	4,904,161	Air	......	......
Ottawa Cutoff........	90	6 x8-7½x9	3200	Cut	14,327,691	Air	......	......
Smithshire, Ill........	90	7½x9	3200	Cut	10,172,186	Air	......	......
Marceline, Mo........	90	7½x9	3200	Cut	10,369,895	Air	......	......
Tecumseh, Kans......	90	7½x9	3200	Cut	5,902,490	Air	......	......
Newton, Kans........	90	6 x8-7½x9	3200	Cut	15,034,755	Air	......	......
Newton, Kans........	85	7½x9	3200	Cut	15,034,755	Air	......	......
Newton, Kans........	85	7½x9	3200	Cut	15,034,755	Air	......	......
Newton, Kans........	85	7½x9	3200	Cut	15,034,755	Air	......	......
Newton, Kans........	85	7½x9	3200	Cut	15,034,755	Air	......	......
Hutchinson Cutoff....	90	7½x9	3200	Screw	4,904,161	Air	......	......
Hutchinson Cutoff....	90	7½x9	3200	Screw	4,904,161	Air	......	......
Hutchinson Cutoff....	90	7½x9	3200	Screw	4,904,161	Air	......	......
Hutchinson Cutoff....	90	7½x9	3200	Screw	4,904,161	Air	......	......
Hutchinson Cutoff....	90	7½x9	3200	Screw	4,904,161	Air	......	......
Hutchinson Cutoff....	90	7½x9	3200	Screw	4,904,161	Air	......	......
Newton, Kans........	85	7½x9	3200	Cut	15,034,755	Air	24	45
Newton, Kans........	85	7½x9	3200	Cut	15,034,755	Air	24	45
Newton, Kans........	85	7½x9	3200	Cut	15,034,755	Air	24	45
Walton, Kans........	85	7½x9	3200	Cut	15,034,755	Air	24	45
Newton, Kans........	90	7½x9	3200	C&S	15,034,755	Air	......	......
Walton, Kans........	90	7½x9	3200	Screw	15,034,755	Air	......	......
Walton, Kans........	90	7½x9	3200	Screw	15,034,755	Air	......	......
Turner-Holliday.......	85	7½x9	3200	Cut	47,966,356	Air	22	30
Turner-Holliday.......	85	7½x9	3200	Cut	47,966,356	Air	23	30
Turner-Holliday.......	85	7½x9	3200	Cut	47,966,356	Air	......	......
Turner-Holliday.......	85	7½x9	3200	Cut	47,966,356	Air	......	......
Turner-Holliday.......	85	7½x9	3200	Cut	47,966,356	Air	......	......
Clements, Kans.......	90	7½x9	3200	Cut	15,034,755	Air	......	......

SPECIAL CROSS-TIE TESTS ON THE SANTA FE SYSTEM (Concluded).

Station or Line	Steam		Air		Pressure		Temp. Retort °F.	Fin. Ins.	Vac. Time	Lbs. Creos.	Absp. Zn Cl_2
	Lbs.	Time	Lbs.	Time	Lbs.	Time					
Marceline, Mo	....	......	60	45	104	1'45"	120	....	.....	4.56	......
Sutton, Kans	....	......	60	45	104	1'45"	120	....	.....	4.56	......
Ponca City, Okla	....	......	60	45	104	1'45"	120	....	.....	4.56	......
Bliss, Okla	....	......	65	50	104	2'15"	122	....	.....	3.93	......
Perry, Okla	....	......	60	45	104	1'45"	120	....	.....	4.56	......
Perry, Okla	....	......	65	50	104	2'15"	122	....	.....	3.93	......
Garnett, Kans	....	......	65	50	104	2'15"	122	....	.....	3.93	......
Argonia, Kans	....	......	65	50	104	2'15"	122	....	.....	3.93	......
Hutchinson Cutoff	....	......	100	30	200	2'30"	186	23	1'30"	5.00	......
Hutchinson Main Line	....	......	100	30	200	2'30"	186	23	1'30"	5.00	......
Plevna, Kans	....	......	100	30	200	2'30"	186	23	1'30"	5.00	......
Plevna, Kans	....	......	100	30	200	2'30"	186	23	1'30"	5.00	......
Ottawa Cutoff	....	......	75	30	150	1'45"	172	22	1'15"	5.00	......
Smithshire, Ill	....	......	50	25	175	3'00"	168	29	1'30"	3.72	......
Marceline, Mo	....	......	50	25	175	3'00"	168	29	1'30"	3.72	......
Tecumseh, Kans	....	......	50	25	175	3'00"	168	29	1'30"	3.72	......
Newton, Kans	....	......	50	25	175	3'00"	168	29	1'30"	3.72	......
Newton, Kans	....	......	85	25	175	1'45"	190	23	1'30"	5.00	......
Newton, Kans	....	......	95	25	175	1'45"	190	23	1'30"	5.00	......
Newton, Kans	....	......	40	25	200	3'30"	190	23	1'30"	5.00	......
Newton, Kans	....	......	60	25	175	2'45"	195	23	1'30"	5.00	......
Hutchinson Cutoff	....	......	85	25	175	1'45"	194	22	1'30"	5.00	......
Hutchinson Cutoff	....	......	65	25	175	1'45"	194	22	1'30"	5.00	......
Hutchinson Cutoff	....	......	100	30	175	3'00"	194	23	2'00"	5.00	......
Hutchinson Cutoff	....	......	....	.....	....	......	......	....	.....	....	......
Hutchinson Cutoff	....	......	....	.....	....	......	......	....	.....	....	......
Hutchinson Cutoff	....	......	85	25	175	1'45"	194	22	1'30"	5.00	......
Newton, Kans	20	3'30"	....	.....	100	2'00"	200	....	.....	....	0.58
Newton, Kans	20	3'30"	....	.....	100	2'00"	200	....	.....	....	0.58
Newton, Kans	20	3'30"	....	.....	100	2'00"	200	....	.....	....	0.52
Walton, Kans	20	3'30"	....	.....	100	2'00"	200	....	.....	....	0.52
Newton, Kans	....	......	75	25	175	1'45"	150	25	1'30"	5.00	......
Walton, Kans	....	......	90	25	175	1'45"	180	25	1'30"	5.00	......
Walton, Kans	....	......	30	25	175	3'00"	180	25	1'30"	4.07	......
Turner-Holliday	20	2'30"	....	.....	175	3'30"	150	....	.....	....	0.56
Turner-Holliday	20	2'30"	....	.....	175	3'30"	150	....	.....	....	0.51
Turner-Holliday	....	......	....	.....	175	1'45"	150	25	1'30"	....	......
Turner-Holliday	....	......	....	.....	175	1'45"	180	25	1'30"	....	......
Turner-Holliday	....	......	....	.....	175	3'00"	180	25	1'30"	....	......
Clements, Kans	....	......	60	45	104	1'45"	120	....	.....	....	......

The Cleveland, Cincinnati, Chicago & St. Louis Railway Company commenced using creosoted ties in its tracks during the year 1905, treated with an average of 7.78 lbs. of oil per cubic foot by the Lowry process. The statement shows 8,816,652 creosoted ties had been inserted in track and 308,996, or 3.5%, removed for all causes at the end of the year 1919. The timber used was principally Ta group, mixed with a small percentage of Tc and Td groups. The increase in percentage of 1906, 1907, 1908 and 1909 ties removed may be attributed to the close method of stacking ties in the storage yard during these years. During 1910 and subsequent years ties have been stacked 1 by 10 with 3- to 4-foot alleys between stacks. The total number of ties inserted in track, treated and untreated, in 1905 was 1,300,661; total number inserted in 1909 was 840,362, a reduction of 460,299 ties, or 35.39%, by using treated ties. There were 369 ties inserted per mile in 1905 and 201 ties per mile in 1919, a reduction of 168 ties per mile. Of the ties inserted in 1905, 31.25% were treated and 68.75% untreated. Of the ties inserted in 1919, 76.96% were treated and 23.04% untreated. During the 15 years mentioned the treated-tie territory was increased and the untreated-tie territory decreased. The mileage in 1919 was 15.57% more than in 1905.

CLEVELAND, CINCINNATI, CHICAGO & ST. LOUIS RAILWAY (INCLUDING PEORIA & EASTERN RAILWAY) CREOSOTED CROSS-TIES APPLIED AND REMOVED, 1905 TO 1919, INCLUSIVE.

Year Put in Track	Number Put in Track	Removed Account Decay			Per Cent Taken Out
		Main Track	Side Track	Total	
1905	406304	16556	3430	19986	4.92
1906	496660	65879	6686	72565	14.61
1907	393988	34906	3414	38320	9.72
1908	463811	20791	3499	24290	5.24
1909	506051	11891	1602	13493	2.66
1910	860379	8106	2309	10415	1.21
1911	558206	4735	508	5243	0.93
1912	724399	1320	546	1866	0.26
1913	672269	246	85	331	0.05
1914	721274	165	108	273	0.04
1915	763783	53	21	74	0.01
1916	567825	71	29	100	0.02
1917	507808	4	......	4	....
1918	527088	......	......	......	....
1919	646772	......	4	4	....
No nails	......	24153	14483	38636	....
TOTAL	8816652	188876	36724	225600	2.56

CLEVELAND, CINCINNATI, CHICAGO & ST. LOUIS RAILWAY (INCLUDING PEORIA & EASTERN RAILWAY) CREOSOTED CROSS-TIES APPLIED AND REMOVED, 1905 TO 1919, INCLUSIVE (Concluded).

Year Put in Track	Number Put in Track	Main Track	Side Track	Total	Per Cent. Taken Out	Total Number Ties Removed	Per Cent. Taken Out. All Causes
1905	406394	5747	1235	6982	1.72	26968	6.64
1906	496660	10044	1202	11246	2.26	83811	16.87
1907	393988	8696	1264	9960	2.53	48230	12.24
1908	463811	8647	1243	9890	2.13	34180	7.37
1909	506051	7962	1881	9843	1.94	23336	4.60
1910	860379	8461	2152	10613	1.23	21028	2.44
1911	558206	5012	1403	6415	1.15	11658	2.08
1912	724399	3155	1668	4821	0.66	6687	0.92
1913	672269	1182	1361	2543	0.37	2874	0.42
1914	721274	1629	1117	2746	0.38	3019	0.42
1915	763788	682	1186	1868	0.24	1942	0.25
1916	567825	498	529	1027	0.18	1127	0.20
1917	507808	159	329	488	0.09	492	0.09
1918	527038	41	211	252	0.04	252	0.04
1919	646772	7	25	32	....	36	....
No Nails	....	3101	1569	4670	....	43306	....
Total...	8816652	65023	18373	83396	0.94	308996	3.50

CROSS-TIE TESTS ON THE CHICAGO, INDIANAPOLIS & LOUISVILLE RAILROAD (MONON ROUTE).

Species	Where Grown	Form. Hewed or Sawed	Dimensions	Where Set	Date Set	Tangent	Per Cent Grade	Number Ties Set	Sealed or Unsealed	Preparation Spacing in Track Inches
White Oak	Indiana	Hewed	6x8x8	Mile 117.9 to 117.1	June, 1914	Yes	5	131	Sealed	20
Red Oak	Indiana	Sawed	6x8x8	117.9 to 117.1	June, 1914	Yes	5	199	Sealed	20
Red Oak	Indiana	Hewed	6x8x8	117.9 to 117.1	June, 1914	Yes	5	198	Sealed	20
Beech......	Indiana	Hewed	6x8x8	117.9 to 117.1	June, 1914	Yes	5	198	Sealed	20
Beech......	Indiana	Sawed	6x8x8	117.9 to 117.1	June, 1914	Yes	5	198	Sealed	20
Elm.......	Indiana	H & S	6x8x8	117.9 to 117.1	June, 1914	Yes	5	200	Sealed	20
So. pine Niger pine	Indiana	Hewed	6x8x8	117.9 to 117.1	June, 1914	Yes	5	196	Sealed	20
Black Walnut....	Indiana	Hewed	6x8x8	117.9 to 117.1	June, 1914	Yes	5	4	Sealed	20
Cherry.....	Indiana	Hewed	6x8x8	117.9 to 117.1	June, 1914	Yes	5	6	Sealed	20
Sassafras...	Indiana	Hewed	6x8x8	117.9 to 117.1	June, 1914	Yes	5	15	Sealed	20
Mulberry...	Indiana	Hewed	6x8x8	117.9 to 117.1	June, 1914	Yes	5	2	Sealed	20

CROSS-TIE TESTS ON THE CHICAGO, INDIANAPOLIS & LOUISVILLE RAILROAD (MONON ROUTE) (Concluded).

Preservative	Process	Average Absorption per Cu. Ft., Lbs.	Average Absorption per Tie, Lbs.	Tie-Plate, Kind, Size	Ballast	Weight of Rail, Lbs.	Spikes, Cut or Screw	Traffic Tons per Year	Per Cent. Removed	Present Condition	Date Inspected
Creosote	Lowry	5.3	22.2	Economy 7"	Gravel	90	Cut	5,697,567	0	Good	Sept., 1920
"	"	7.7	20.6	"	"	90	"	5,697,567	0	"	"
"	"	[illegible].7	20.6	"	"	90	"	5,697,567	0	"	"
"	"	11.3	30.1	"	"	90	"	5,697,567	0	"	"
"	"	7.0	18.7	"	"	90	"	5,697,567	0	"	"
"	"	8.7	23.3	"	"	90	"	5,697,567	0	"	"
"	"	9.2	24.5	"	"	90	"	5,697,567	0	"	"
"	"	4.6	12.4	"	"	90	"	5,697,567	0	"	"
"	"	7.3	19.4	"	"	90	"	5,697,567	0	"	"
"	"	3.1	9.4	"	"	90	"	5,697,567	0	"	"
"	"	1.3	3.5	"	"	90	"	5,697,567	0	"	"

STATUS OF CROSS-TIES IN TEST SECTIONS ON ST. LOUIS-SAN FRANCISCO RAILWAY, AT CLOSE OF CALENDAR YEAR 1919.

Location of Test Track	Kind of Wood	Kind of Treatment	Year in Track	Original Number in Track	Per Cent Removed	Annual Tonnage
Sulligent, Ala.	White oak	Unt'd.	1914	944	77.4	3,630,000
Memphis, Tenn.	White oak	Unt'd.	1914	831	23.2	3,180,000
Diggins, Mo.	White oak	Unt'd.	1914	1342	17.2	3,940,000
Eureka, Mo.	White oak	Unt'd.	1914	1081	12.1	6,920,000
Afton, Okla.	White oak	Unt'd.	1914	252	6.3	6,490,000
Poteau, Okla.	White oak	Unt'd.	1914	142	27.0	1,030,000
Woodville, Okla.	White oak	Unt'd.	1914	655	15.4	2,270,000
Valley Center, Kans.	White oak	Unt'd.	1914	408	7.7	420,000
Bonita, Kans.	White oak	Unt'd.	1914	861	13.7	7,540,000
Sulligent, Ala.	White oak	Unt'd.	1915	373	67.8	3,630,000
Memphis, Tenn.	White oak	Unt'd.	1915	968	11.3	3,180,000
Diggins, Mo.	White oak	Unt'd.	1915	473	6.4	3,940,000
Eureka, Mo.	White oak	Unt'd.	1915	613	16.0	6,920,000
Afton, Okla.	White oak	Unt'd.	1915	193	11.4	6,390,000
Poteau, Okla.	White oak	Unt'd.	1915	250	0.0	1,030,000
Woodville, Okla.	White oak	Unt'd.	1915	599	5.5	2,270,000
Valley Center, Kans.	White oak	Unt'd.	1915	348	1.1	420,000
Bonita, Kans.	White oak	Unt'd.	1915	601	8.0	7,540,000
St. Clair, Mo.	Red oak	Rueping	1906	752	24.1	6,920,000
St. Clair, Mo.	Gum	Rueping	1906	321	12.5	6,920,000
Diggins, Mo.	Red oak	Lowry	1908	103	5.0	3,940,000
Eureka, Mo.	Red oak	Lowry	1908	136	1.5	6,920,000
Afton, Okla.	Red oak	Lowry	1908	293	0.3	6,490,000
Poteau, Okla.	Red oak	Lowry	1908	90	0.0	1,030,000
Valley Center, Kans.	Red oak	Lowry	1908	190	0.0	420,000
Bonita, Kans.	Red oak	Lowry	1908	329	44.4	7,540,000
Diggins, Mo.	Red oak	Lowry	1909	476	6.8	3,940,000
Eureka, Mo.	Red oak	Lowry	1909	394	2.0	6,920,000
Afton, Okla.	Red oak	Lowry	1909	1312	1.7	6,390,000
Woodville, Okla.	Red oak	Lowry	1909	94	0.0	2,270,000
Valley Center, Kans.	Red oak	Lowry	1909	268	0.0	420,000
Bonita, Kans.	Red oak	Lowry	1909	532	18.3	7,540,000
Diggins, Mo.	Red oak	Lowry	1910	219	6.0	3,940,000
Eureka, Mo.	Red oak	Lowry	1910	135	0.0	6,920,000
Poteau, Okla.	Red oak	Lowry	1910	74	1.3	1,030,000
Valley Center, Kans.	Red oak	Lowry	1910	68	0.0	420,000
Eureka, Mo.	Gum	Lowry	1908	198	8.5	6,920,000
Afton, Okla.	Gum	Lowry	1908	107	3.8	6,490,000
Woodville, Okla.	Gum	Lowry	1908	56	0.0	2,270,000
Valley Center, Kans.	Gum	Lowry	1908	398	0.8	420,000
Bonita, Kans.	Gum	Lowry	1908	224	14.7	7,540,000
Eureka, Mo.	Gum	Lowry	1909	155	0.6	6,920,000
Afton, Okla.	Gum	Lowry	1909	199	3.0	6,490,000
Afton, Okla.	Pine	Lowry	1908	63	11.1	6,490,000
Poteau, Okla.	Pine	Lowry	1908	69	1.7	1,030,000
Woodville, Okla.	Pine	Lowry	1908	298	19.8	2,270,000
Afton, Okla.	Pine	Lowry	1909	120	10.3	6,490,000
Poteau, Okla.	Pine	Lowry	1909	154	3.9	1,030,000
Woodville, Okla.	Pine	Lowry	1909	648	6.1	2,270,000
Woodville, Okla.	Pine	Lowry	1910	71	4.3	2,270,000
Eureka, Mo.	Elm	Lowry	1909	90	0.0	6,920,000

CREOSOTED CROSS-TIES (LOWRY PROCESS) ON THE CHICAGO, ROCK ISLAND & PACIFIC RAILWAY.

Location	Kind of Ties	Number	Year Inserted	Per Cent Removed—All Causes, to Dec. 31, 1919	Traffic Tons per Year (1919)
Tiskilwa, Ill	Red oak	642	1908	11.06	11,000,000
Altoona, Ia	Red oak	276	1908	8.00	7,200,000
Princeton, Mo	Red oak	216	1908	18.50	10,500,000
Ely, Ia	Red oak	1195	1908	7.20	8,000,000
Clarksville, Ia	Red oak	1647	1908	0.54	5,400,000
West Bend, Ia	Red oak	149	1908	2.70	3,800,000
Fairbury, Neb	Red oak	508	1908	2.90	3,000,000
Goodland, Kans	Red oak	88	1908	9.00	3,100,000
Total		4721		5.40	
Tiskilwa, Ill	Red oak	1529	1909	6.01	11,000,000
Altoona, Ia	Red oak	1396	1909	1.90	7,200,000
Princeton, Mo	Red oak	479	1909	7.10	10,500,000
Ely, Ia	Red oak	976	1909	47.90	8,000,000
Clarksville, Ia	Red oak	1592	1909	1.25	5,400,000
Fairbury, Neb	Red oak	321	1909	0.30	3,000,000
Goodland, Kans	Red oak	1118	1909	0.26	3,100,000
Topeka, Kans	Red oak	1073	1909	7.00	10,300,000
Total		8484		8.47	
Tiskilwa, Ill	Red oak	3293	1910	2.80	11,000,000
Altoona, Ia	Red oak	594	1910	2.30	7,200,000
Princeton, Mo	Red oak	1002	1910	3.50	10,500,000
Ely, Ia	Red oak	2355	1910	5.90	8,000,000
Clarksville, Ia	Red oak	1481	1910	0.30	5,400,000
Fairbury, Neb	Red oak	1749	1910	0.90	3,000,000
Eldon, Mo	Red oak	4200	1910	0.90	3,200,000
Topeka, Kans	Red oak	522	1910	1.16	10,300,000
Total		15196		2.20	
Tiskilwa, Ill	Red oak	1262	1911	1.11	11,800,000
Altoona, Ia	Red oak	791	1911	2.40	7,200,000
Princeton, Mo	Red oak	1914	1911	0.70	10,500,000
Ely, Ia	Red oak	2256	1911	1.80	8,000,000
West Bend, Ia	Red oak	89	1911	0.00	3,800,000
Fairbury, Neb	Red oak	52	1911	0.00	3,000,000
Goodland, Kans	Red oak	105	1911	0.00	3,100,000
Eldon, Mo	Red oak	2423	1911	1.32	3,200,000
Total		8892		1.33	
Tiskilwa, Ill	Red oak	211	1912	0.00	11,000,000
Altoona, Ia	Red oak	770	1912	0.80	7,200,000
Ely, Ia	Red oak	459	1912	0.00	8,000,000
Princeton, Mo	Red oak	331	1912	17.50	10,500,000
E. Des Moines, Ia	Red oak	5526	1912	0.34	4,100,000
Goodland, Kans	Red oak	72	1912	0.00	3,100,000
Eldon, Mo	Red oak	2423	1912	1.30	3,200,000
Total		9792		1.18	
Tiskilwa, Ill	Red oak	61	1913	18.00	11,000,000
Altoona, Ia	Red oak	728	1913	41.00	7,200,000
Princeton, Mo	Red oak	1028	1913	28.00	10,500,000
Ely, Ia	Red oak	1600	1913	3.50	8,000,000
Clarksville, Ia	Red oak	262	1913	3.05	5,400,000
Eldon, Mo	Red oak	1268	1913	0.00	3,200,000
Topeka, Kans	Red oak	676	1913	0.90	10,300,000
Total		5623		11.90	

CREOSOTED CROSS-TIES (LOWRY PROCESS) ON THE CHICAGO, ROCK ISLAND & PACIFIC RAILWAY (Continued).

Location	Kind of Ties	Number	Year Inserted	Per Cent Removed—All Causes, to Dec. 31, 1919	Traffic Tons per Year (1919)
Tiskilwa, Ill	Red oak	1256	1914	0.00	11,000,000
Altoona, Ia	Red oak	2075	1914	3.32	7,200,000
Princeton, Mo	Red oak	632	1914	3.68	10,500,000
Ely, Ia	Red oak	2038	1914	4.85	8,000,000
Eldon, Mo	Red oak	553	1914	3.61	3,200,000
Topeka, Kans	Red oak	765	1914	0.90	10,300,000
Total		7319		2.84	
Dalhart, Tex	Pine	820	1908	4.30	4,300,000
Ely, Ia	Pine	214	1909	6.07	8,000,000
E. Des Moines, Ia	Pine	390	1909	0.80	4,100,000
Goodland, Kans	Pine	129	1909	2.30	3,100,000
Total		733		2.60	
Ely, Ia	Pine	102	1910	63.00	8,000,000
West Bend, Ia	Pine	69	1910	17.40	5,400,000
E. Des Moines, Ia	Pine	155	1910	0.00	4,100,000
Fairbury, Neb	Pine	233	1910	0.00	3,000,000
Goodland, Kans	Pine	737	1910	4.30	3,100,000
Topeka, Kans	Pine	487	1910	13.50	10,300,000
Total		1783		9.80	
Tiskilwa, Ill	Pine	91	1911	7.70	11,000,000
Clarksville, Ia	Pine	1015	1911	0.19	5,400,000
West Bend, Ia	Pine	821	1911	1.82	3,800,000
E. Des Moines, Ia	Pine	56	1911	5.30	4,100,000
Fairbury, Neb	Pine	1502	1911	1.80	3,000,000
Goodland, Kans	Pine	1603	1911	0.18	3,100,000
Topeka, Kans	Pine	160	1911	8.80	10,300,000
Total		5248		1.36	
Ely, Ia	Pine	345	1912	0.00	8,000,000
Clarksville, Ia	Pine	1045	1912	0.00	5,400,000
West Bend, Ia	Pine	711	1912	0.28	3,800,000
Fairbury, Neb	Pine	1376	1912	0.14	3,000,000
Goodland, Kans	Pine	536	1912	0.00	3,100,000
Topeka, Kans	Pine	261	1912	0.10	10,300,000
Dalhart, Tex	Pine	240	1912	0.00	4,300,000
Total		4514		0.17	
Ely, Ia	Pine	80	1913	1.20	8,000,000
Clarksville, Ia	Pine	724	1913	0.27	5,400,000
Fairbury, Neb	Pine	1074	1913	0.09	3,000,000
Goodland, Kans	Pine	2271	1913	0.40	3,100,000
Topeka, Kans	Pine	374	1913	1.07	10,300,000
Dalhart, Tex	Pine	141	1913	3.50	4,300,000
Total		4664		0.51	
Clarksville, Ia	Pine	635	1914	1.10	5,400,000
Fairbury, Neb	Pine	703	1914	0.00	3,000,000
Goodland, Kans	Pine	2438	1914	0.00	3,100,000
Topeka, Kans	Pine	602	1914	0.50	10,300,000
Total		4378		0.25	

CREOSOTED CROSS-TIES (LOWRY PROCESS) ON THE CHICAGO, ROCK ISLAND & PACIFIC RAILWAY (Continued).

Location	Kind of Ties	Number	Year Inserted	Per Cent Removed—All Causes, to Dec. 31, 1919	Traffic Tons per Year (1919)
Tiskilwa, Ill	Gum	80	1908	35.00	11,000,000
Ely, Ia	Gum	391	1908	17.30	8,000,000
Clarksville, Ia	Gum	96	1908	3.12	5,400,000
West Bend, Ia	Gum	887	1908	2.90	3,800,000
E. Des Moines, Ia	Gum	99	1908	4.00	4,100,000
Fairbury, Neb	Gum	114	1908	0.90	3,000,000
Total		1667		7.70	
Tiskilwa, Ill	Gum	58	1909	5.16	11,000,000
Altoona, Ia	Gum	63	1909	0.00	7,200,000
Ely, Ia	Gum	126	1909	18.00	8,000,000
West Bend, Ia	Gum	539	1909	0.74	3,800,000
E. Des Moines, Ia	Gum	624	1909	4.10	4,100,000
Total		1410		3.90	
Ely, Ia	Gum	159	1910	3.70	8,000,000
West Bend, Ia	Gum	279	1910	1.08	3,800,000
E. Des Moines, Ia	Gum	331	1910	3.60	4,100,000
Dalhart, Tex	Gum	64	1910	3.10	4,300,000
Total		833		2.76	
Altoona, Ia	Gum	306	1911	0.90	7,200,000
Princeton, Mo	Gum	739	1911	6.60	10,500,000
Fairbury, Neb	Gum	71	1911	8.40	3,000,000
Total		1116		5.20	
Tiskilwa, Ill	Gum	741	1912	0.00	11,000,000
Ely, Ia	Gum	1238	1912	3.50	8,000,000
E. Des Moines, Ia	Gum	1263	1912	0.40	4,100,000
Total		3242		1.50	
Tiskilwa, Ill	Gum	892	1913	0.33	11,000,000
Ely, Iowa	Gum	126	1913	0.00	8,000,000
Topeka, Kans	Gum	545	1913	0.00	10,300,000
Dalhart, Tex	Gum	141	1913	3.50	4,300,000
Total		1704		0.46	
Tiskilwa, Ill	Gum	1415	1914	4.90	11,000,000
Clarksville, Ia	Gum	409	1914	0.00	5,400,000
Goodland, Kans	Gum	357	1914	0.00	3,100,000
Eldon, Mo	Gum	429	1914	0.00	3,200,000
Topeka, Kans	Gum	408	1914	1.40	10,300,000
Total		3018		0.43	
Altoona, Ia	Elm	64	1908	0.00	7,200,000
Clarksville, Ia	Elm	101	1908	0.90	5,400,000
West Bend, Ia	Elm	238	1908	1.68	3,800,000
Total		403		1.24	
Altoona, Ia	Elm	64	1909	0.00	7,200,000
E. Des Moines, Ia	Elm	188	1909	4.70	4,100,000
Total		251		3.50	

CREOSOTED CROSS-TIES (LOWRY PROCESS) ON THE CHICAGO, ROCK ISLAND & PACIFIC RAILWAY (Concluded).

Location	Kind of Ties	Number	Year Inserted	Per Cent Removed—All Causes, to Dec. 31, 1919	Traffic Tons per Year (1919)
Altoona, Ia.	Elm	148	1911	0.00	7,200,000
Ely, Ia.	Elm	146	1912	4.80	8,000,000
E. Des Moines, Ia.	Elm	231	1912	0.00	4,100,000
Total		377		1.60	
Princeton, Mo.	Elm	127	1914	3.80	10,500,000

ZINC TREATED TIES ON THE CHICAGO, ROCK ISLAND & PACIFIC RAILWAY.

Location	Kind of Ties	Number	Year Inserted	Per Cent Removed—All Causes, to Dec. 31, 1919	Traffic Gross Tons per Year (1919)
Ola, Ark	Red oak	741	1909	6.20	4,600,000
Yukon, Okla	Red oak	672	1909	4.31	5,500,000
Heywood, Okla	Red oak	225	1909	28.00	5,500,000
Total		1638		8.40	
Ola, Ark	Red oak	68	1910	13.23	4,600,000
Heywood, Okla	Red oak	586	1910	4.60	5,500,000
Total		654		5.50	
Heywood, Okla	Red oak	270	1911	8.52	5,500,000
Okarche, Okla	Red oak	149	1911	0.00	5,000,000
Yukon, Okla	Red oak	418	1911	2.87	5,500,000
McLean, Tex	Red oak	545	1911	1.83	1,720,000
Total		1382		3.32	
Yukon, Okla	Red oak	373	1912	0.53	5,500,000
McLean, Tex	Red oak	171	1912	11.11	1,720,000
Total		544		3.86	
Heywood, Okla	Red oak	480	1913	13.33	5,500,000
Okarche, Okla	Red oak	269	1913	0.00	5,000,000
Yukon, Okla	Red oak	462	1913	0.64	5,500,000
Total		1211		5.53	
Ola, Ark	Red oak	266	1914	0.00	4,600,000
Heywood, Okla	Pine	2459	1908	27.16	5,500,000
McLean, Tex	Pine	3274	1908	46.51	1,720,000
Chico, Tex	Pine	845	1908	28.99	2,140,000
Total		6578		36.88	
Ola, Ark	Pine	1066	1909	13.88	4,600,000
Leola, Ark	Pine	1324	1909	19.86	1,400,000
Heywood, Okla	Pine	2187	1909	22.45	5,500,000
Okarche, Okla	Pine	481	1909	2.28	5,000,000
Yukon, Okla	Pine	1622	1909	16.27	5,500,000
Chico, Tex	Pine	2764	1909	18.81	2,140,000
Total		9444		17.96	
Ola, Ark	Pine	430	1910	7.44	4,600,000
Leola, Ark	Pine	1868	1910	10.00	1,400,000
Heywood, Okla	Pine	877	1910	21.09	5,500,000
Okarche, Okla	Pine	844	1910	1.18	5,000,000
Yukon, Okla	Pine	1003	1910	3.48	5,500,000
Total		5022		8.92	
Ola, Ark	Pine	5116	1911	16.22	4,600,000
Leola, Ark	Pine	277	1911	2.17	1,400,000
Heywood, Okla	Pine	960	1911	11.14	5,500,000
Okarche, Okla	Pine	1044	1911	3.64	5,000,000
Yukon, Okla	Pine	1486	1911	11.42	5,500,000
Chico, Tex	Pine	2223	1911	8.23	2,140,000
Total		11106		11.42	

ZINC TREATED TIES ON THE CHICAGO, ROCK ISLAND & PACIFIC RAILWAY (Concluded).

Location	Kind of Ties	Number	Year Inserted	Per Cent Removed—All Causes, to Dec. 31, 1919	Traffic Gross Tons per Year (1919)
Dalhart, Tex	Pine	641	1912	0.00	4,300,000
Ola, Ark	Pine	1252	1912	1.35	5,000,000
Leola, Ark	Pine	1817	1912	5.55	1,400,000
Heywood, Okla	Pine	1042	1912	13.43	5,500,000
Okarche, Okla	Pine	1600	1912	2.25	5,000,000
Yukon, Okla	Pine	1584	1912	1.64	5,500,000
Chico, Tex	Pine	1342	1912	26.45	2,140,000
Total		9278		7.27	
Dalhart, Tex	Pine	1385	1913	0.00	4,300,000
Leola, Ark	Pine	1715	1913	1.10	1,400,000
Heywood, Okla	Pine	950	1913	11.16	5,500,000
Okarche, Okla	Pine	945	1913	10.80	5,000,000
Yukon, Okla	Pine	1868	1913	1.07	5,500,000
Chico, Tex	Pine	1431	1913	6.77	2,140,000
Total		8294		3.93	
Ola, Ark	Pine	97	1914	0.00	5,000,000
Leola, Ark	Pine	368	1914	4.89	1,400,000
Heywood, Okla	Pine	984	1914	2.54	5,500,000
Okarche, Okla	Pine	708	1914	0.56	5,000,000
Yukon, Okla	Pine	1927	1914	2.02	5,500,000
McLean, Tex	Pine	328	1914	0.30	1,720,000
Chico, Tex	Pine	891	1914	2.13	2,140,000
Total		5303		2.00	
McLean, Tex	Gum	338	1908	23.90	1,720,000
Ola, Ark	Gum	82	1909	15.85	5,000,000
Leola, Ark	Gum	385	1909	12.72	1,400,000
Heywood, Okla	Gum	564	1909	21.27	5,500,000
Okarche, Okla	Gum	77	1909	0.00	5,000,000
Yukon, Okla	Gum	571	1909	5.78	5,500,000
Total		1679		12.86	
Leola, Ark	Gum	80	1910	15.00	1,400,000
Okarche, Okla	Gum	73	1910	0.00	5,000,000
Total		153		7.84	
Ola, Ark	Gum	65	1911	9.23	4,600,000
Okarche, Okla	Gum	151	1911	3.31	5,000,000
Total		216		5.09	
Okarche, Okla	Gum	208	1912	0.00	5,000,000
Leola, Ark	Gum	382	1914	0.52	1,400,000
Heywood, Okla	Gum	567	1914	11.90	1,400,000
Total		949		7.37	
Ola, Ark	Red oak	50	1914	0.00	4,600,000
Yukon, Okla	Red oak	117	1914	19.60	5,500,000
Total		167		14.36	
Dalhart, Tex	Pine	1820	1914	1.09	4,300,000
Heywood, Okla	Pine	292	1914	22.36	5,500,000
Okarche, Okla	Pine	888	1914	1.35	5,000,000
Chico, Tex	Pine	596	1914	18.62	2,140,000
Total		3596		5.28	

RECORD OF CROSS-TIE TESTS ON BALTIMORE & OHIO RAILROAD. (Corrected to October, 1920.)

Location	Kind of Wood	Treatment	Number Originally Inserted	Year	Number Left in Test Track	Per Cent Removed		Tonnage Traffic Per year *
						Account Decay	Account Other Causes	
Windsor, Ohio	Ash	Zn. & coal-tar creo.	3	1911	3			29,251
Windsor, Ohio	Beech	Coal-tar-creo.	27	1911	27			29,251
Windsor, Ohio	Beech	Zn. & coal-tar creo.	571	1911	536		6.0	29,251
N. Dayton, Ohio	Beech	Untreated	50	1919	50			57,912
N. Dayton, Ohio	Beech	Zn. & water-gas tar	101	1919	101			57,912
Boyds, Md.	Beech	Zn. & water-gas tar	64	1919	64			11,738
Boyds, Md.	Beech	Zn. & W. G. T. creo. & coal-tar creo.	54	1919	54			11,738
Barnesville, Md.	Beech	Zn. & W. G. tar	5	1919	5			5,371
Barnesville, Md.	Red Birch	Zn. & W. G. tar	45	1919	45			5,371
N. Dayton, Ohio	Cherry	Untreated	27	1919	27			57,912
N. Dayton, Ohio	Cherry	Zn. & W. G. tar	32	1919	32			57,912
N. Dayton, Ohio	Chestnut	Untreated	50	1919	50			57,912
N. Dayton, Ohio	Chestnut	Zn. & W. G. tar	95	1919	95			57,912
Windsor, Ohio	Elm	Zn. & coal-tar creo.	51	1911	51			29,251
Windsor, Ohio	Elm	Coal-tar creo.	37	1911	37			29,251
Windsor, Ohio	Elm	Tbr. asphalt	12	1911	12			29,251
N. Dayton, Ohio	Elm	Untreated	25	1919	25			57,912
N. Dayton, Ohio	Elm	Zn. & W. G. tar	34	1919	34			57,912
N. Dayton, Ohio	D. fir	Untreated	105	1919	105			57,912
N. Dayton, Ohio	D. fir	Zn. & W. G. tar	155	1919	155			57,912
Barnesville, Md.	D. fir	Untreated	105	1919	105			5,371
Barnesville, Md.	D. fir	Zn. & W. G. tar	105	1919	105			5,371
Windsor, Ohio	Gum	Zn. & coal-tar creo.	125	1911	115		8.0	29,251
Windsor, Ohio	Gum	Coal-tar creo.	118	1911	109		8.0	29,251
Windsor, Ohio	Gum	Tbr. asphalt	3	1911	3			29,251
Boyds, Md.	Gum	Zinc & W. G. tar	2	1915	2			11,738
Boyds, Md.	Gum	Zn. & W. G. T. and coal-tar creo.	2	1915	2			11,738

*In 1,000 tons.

RECORD OF CROSS-TIE TESTS ON BALTIMORE & OHIO RAILROAD. (Corrected to October, 1920.) (Continued).

Location	Kind of Wood	Treatment	Number Originally Inserted	Year	Number Left in Test Track	Per Cent Removed		Tonnage Traffic Per Year *
						Account Decay	Account Other Causes	
Windsor, Ohio	Hickory	Zn. & coal-tar creo.	1	1911	1			29,251
Barnesville, Md.	Hickory	Zn. & W. G. tar	4	1919	4			5,371
Windsor, Ohio	H. maple	Zn. & coal-tar creo.	475	1911	481		9.0	29,251
Windsor, Ohio	H. maple	Tbr. asphalt	2	1911	2			29,251
Windsor, Ohio	H. maple	Coal-tar creo.	67	1911	67			29,251
Boyds, Md.	H. maple	Zn. & W. G. tar	6	1915	6			11,738
Boyds, Md.	H. maple	Zn. & W. G. T. & coal-tar creo.	6	1915	6			11,738
Barnesville, Md.	H. maple	Zn. & W. G. tar	49	1919	49			5,371
Barnesville, Md.	S. maple	Zn. & W. G. tar	55	1919	55			5,371
Staten Island, N. Y.	Black oak	Untreated	25	1915	2	92.0		540
Staten Island, N. Y.	Black oak	Zn. & coal-tar creo.	105	1915	105			540
Staten Island, N. Y.	Chestnut	Untreated	25	1915	25			540
Staten Island, N. Y.	Chestnut	Zn. & coal-tar creo.	105	1915	105			540
Windsor, Ohio	Red oak	Zn. & coal-tar creo.	1118	1911	1095		2.0	29,251
Windsor, Ohio	Red oak	Coal-tar creo.	872	1911	869		0.3	29,251
Windsor, Ohio	Red oak	Tbr. asphalt	984	1911	559	41.0	2.0	29,251
Boyds, Md.	Red oak	Zn. & W. G. tar	451	1915	450		0.22	11,738
Boyds, Md.	Red oak	Zn. & W. G. tar & C. T. C.	133	1915	133			11,738
Staten Island, N. Y.	Red oak	Untreated	25	1915	4	84.0		540
Staten Island, N. Y.	Red oak	Zn. & coal-tar creo.	105	1915	105			540
N. Dayton, Ohio	Red oak	Untreated	48	1919	48			57,912
N. Dayton, Ohio	Red oak	Zn. & W. G. tar	103	1919	103			57,912
Hamden, Ohio	Red oak	Untreated	25	1917	25			32,176
Hamden, Ohio	Red oak	Zn. & W. G. tar	100	1917	100			32,176
LaPaz Jct., Ind.	Red oak	Zn. & coal-tar creo.	981	1917	981			3,189

*In 1,000 tons.

RECORD OF CROSS-TIE TESTS ON BALTIMORE & OHIO RAILROAD. (Corrected to October, 1920.) (Continued).

Location	Kind of Wood	Treatment	Number Originally Inserted	Year	Number Left in Test Track	Per Cent Removed		Tonnage Traffic Per Year *
						Account Decay	Account Other Causes	
Green Spring, W. Va.	Red oak	Zn. & coal-tar creo.	10	1914	10			600
Green Spring, W. Va.	Red oak	Coal T. C.—10 lbs.	10	1914	10			600
Green Spring, W. Va.	Red oak	Coal T. C.— 6 lbs.	10	1914	10			600
Green Spring, W. Va.	Red oak	Zn. & W. G. tar & coal-tar creo	10	1914	10			600
Green Spring, W. Va.	Red oak	Untreated	10	1914		100.00		600
Green Spring, W. Va.	Red oak	Zn. & W. G. tar	10	1914	10			600
Herring Run, Md.	Red oak	Coal-tar-creo.— 4 lbs.	300	1914	300			14,517
Herring Run, Md.	Red oak	Coal-tar-creo.—10 lbs.	300	1914	300			14,517
Herring Run, Md.	Red oak	Sodium fluoride	300	1914	299		0.33	14,517
Herring Run, Md.	Red oak	Untreated	298	1914	110	60.00	3.00	14,517
Herring Run, Md.	Red oak	W. G. tar—5 lbs.	150	1914	150			14,517
Herring Run, Md.	Red oak	W. G. tar—6 lbs.	150	1914	150			14,517
Herring Run, Md.	Red oak	W. G. tar—7 lbs.	150	1914	149		0.66	14,517
Herring Run, Md.	Red oak	W. G. tar—11 lbs.	362	1914	359		0.83	14,517
Herring Run, Md.	Red oak	Zn. Cl 2—0.35 lb.	300	1914	172		43.00	14,517
Herring Run, Md.	Red oak	Zn. Cl 2—0.63 lb.	300	1914	213		29.00	14,517
Herring Run, Md.	Red oak	Zn. coal-tar creo.	600	1914	592		1.33	14,517
Herring Run, Md.	Red oak	Zn. W. G. tar & coal tar-creo.	300	1914	299		1.33	14,517
Windsor, Ohio	White oak	Untreated	761	1911	341	52.00	3.00	29,251
Boyds, Md.	White oak	Untreated	4	1915	4			11,738
Staten Island, N. Y.	White oak	Untreated	25	1915	25			540
Staten Island, N. Y.	White oak	Zn. & C. T. creo.	104	1915	104			540
Hamden, Ohio	White oak	Untreated	25	1917	25			32,176
Hamden, Ohio	White oak	Zn. & W. G. tar	100	1917	100			32,176
N. Dayton, Ohio	White oak	Untreated	99	1919	99			57,912
N. Dayton, Ohio	White oak	Zn. & W. G. tar	96	1919	96			57,912

*In 1,000 tons.

RECORD OF CROSS-TIE TESTS ON BALTIMORE & OHIO RAILROAD. (Corrected to October, 1920.) (Concluded.)

Location	Kind of Wood	Treatment	Number Originally Inserted	Year	Number Left in Test Track	Per Cent Removed		Tonnage Traffic Per Year *
						Account Decay	Account Other Causes	
Hamden, Ohio	Water oak	Untreated	25	1917	25			32,176
Hamden, Ohio	Water oak	Zn. & W. G. tar	100	1917	100			32,176
N. Dayton, Ohio	Ht. pine	Untreated	50	1919	50			57,912
Windsor, Ohio	Sap pine	Coal-tar creo.	1	1911	1			29,251
N. Dayton, Ohio	Sap pine	Zn. & W. G. tar	92	1919	92			57,912
Barnesville, Md.	Ht. pine	Untreated	50	1919	50			5,371
Barnesville, Md.	Sap pine	Zn. & W. G. tar	52	1919	52			5,371
Barnesville, Md.	Sycamore	Zn. & W. G. tar	50	1919	50			5,371
Windsor, Ohio	Bl. Walnut	Coal-tar creo.	1	1911	1			29,251
Windsor, Ohio	W. Walnut	Zn. & C. T. creo.	1	1911	1			29,251

*In 1,000 tons.

MR. S. D. COOPER: The original instructions to the Committee were that they were to make a critical study of tie-records, especially with regard to the treatment with chloride of zinc, but, unfortunately, on account of the unsettled conditions they were unable to do that and confined their attention to getting the test-records from the railroads mentioned in this report. There are representatives here from the Chicago, Rock Island & Pacific Railway Company and the Baltimore & Ohio Railroad Company who, I am sure, would no doubt be glad to give you a brief outline of the tests which relate to their particular roads.

Before I sit down I will refer briefly to one test on the Santa Fe records. In 1906 on the Ottawa cut-off, which is the main-line passenger and freight, between Newton and Kansas City, there were 24,238 ties treated with approximately 5 lbs. of creosote to the cubic foot by the Rueping process, and at the last inspection, in September, 1920, there were 23,881 ties still in the track, practically 98% of them, and of those taken out of the track they were all taken out for cause, that is, on account of a bad wreck that we had when one of the trains went off the track.

I mention this particularly for the reason that was the year the Santa Fe first commenced to treat large numbers of ties by the Rueping process. There was no idea of these ties being used as a test, and it was simply by accident in traveling over the division with the superintendent that he told me that in 1914 he was laying new rail and that he had not taken out a tie, and, in fact, had not removed the outside spike, so I went down to Melvern and counted the ties in the track and we have been carrying it on as a test ever since.

On recent inspection, less than 2 weeks ago, with a representative of the Southern Pacific, it is a fair estimate to think that we would have from 5 years to 6 years more life out of the ties in the track.

MR. O. C. STEINMAYER: Mr. Chairman, the tests on the St. Louis-San Francisco Railroad have not been carried on for a sufficiently long period of time to warrant any definite conclusions being made at this time. The number of untreated ties that have been taken out since these tests were inaugurated would indicate that we are getting approximately 8 years' life out of our white oak ties, but this varies considerably in various districts. In Alabama and Mississippi it is something like 5½ years, whereas in western Kansas it is over 9 years. Of our creosoted ties, although many of them have been in use for 12 years, the per cent. taken out to date is sufficient only to estimate the possible average life which we will obtain from them. This we now think will be some 15 to 20 years.

MR. C. F. FORD (Chicago, Rock Island & Pacific Railway): We have been using creosoted ties about the same length of time as the Frisco. We are now maintaining 19 test-sections, one being located on each operating division. An inventory was taken of all ties in track on each test-section. After the tie-renewals for each year are completed, each test-section is checked by a representative of this department and the inventory is then brought up to date, which enables us to ascertain the number of treated ties inserted and removed during the year. We are unable at the present time to determine the life of our treated ties, but as an illustration of the service they are rendering, we have 5,214 creosoted oak ties in various test-sections that were inserted in 1908, of which only 5.4% have been removed to date. These records will be brought up to date each year, and included in report to the Forest Products Laboratory.

MR. F. J. ANGIER: Mr. Chairman and Gentlemen, the test tracks on the Baltimore & Ohio are not so very old. We have one test-track about 6 miles east of Baltimore, where we put in 3,300 red oak ties, treated in 10 different ways. First, we have 300 cross-ties untreated, 300 treated with zinc chloride, 300 with sodium fluoride, and the same number with water-gas tar, coal-tar creosote, and a mixture of water-gas tar, coal-tar creosote and zinc chloride. These tests were put in 1914, and an inspection made in October showed not a single treated tie of any kind removed on account of decay, and about 83% of the untreated had failed on account of decay in 6 years.

On the Staten Island lines we put in 1915, about 5 years ago, 1,000 ties, divided among red oak, black oak, chestnut oak, and white oak. These ties were all treated with the Card process of 0.5 lb. of zinc chloride and 3 lbs. of creosote. The record here shows that of the untreated red oak ties, 84% have been removed, and of the black oak, 92%. The chestnut oak and white oak are still in track after 5 years.

At Dayton, Ohio, we put in a test-track only recently, in 1919, and there has not been time enough to get any results. We have test-tracks in other places, and they have only been put in recently. At Green Spring we put in some ties, treated and untreated, in 1914. The untreated ties have all been removed for decay. These were red oak ties. None of the treated ties have been removed. We have found that the tonnage-traffic over these test-tracks varies from 5,000,000 to 55,000,000 tons annually. We expect in time to get some very good results from our test-tracks.

THE PRESIDENT: The report of this Committee is excellent. We will be very glad to have discussion while the Committee is on the floor. Mr. Kirkbride, would you care to discuss this report?

MR. W. H. KIRKBRIDE: Well, I do not feel in position to discuss the report. I have not had an opportunity to review those papers. My impression is this: I do not refer particularly to the reports that have been presented, but it seems to me there is a poverty of information whenever we begin to talk about the life of ties. I appreciate, myself, that it is very difficult to put your finger right down on facts and say you are getting such a life out of a certain kind of tie. Railroads start experiments, but unfortunately, the constant changing of foremen and roadmasters and higher officials leads to the fact that the experiment goes by the board sooner or later, and the information obtained, even from the experiments, is unreliable. I think that some very constructive work could be done by developing the proper methods of getting correct data on experiments. I think that is one of the best things that committees could go into. Experiments must last from 5 years to 20 years, and methods must be outlined so that correct reports can be obtained.

We, on the Pacific Coast, have not experimented very much with creosoted ties, although it has been my good fortune to follow a number of such tests. I have in mind a certain batch of 69 ties that were creosoted, and a certain proportion of these ties lasted 20 years under the following adverse conditions: The 69 ties were placed alongside of 5 other groups of experimental ties, all under 50-lb. rail, tangent track, imperfect ballast; they passed through the following changes,—the 50-lb. rail was run to broken joints, later on Wolhaupter tie-plates were applied, later on the line was ballasted, then laid with 75-lb. rail and reballasted with a better grade of ballast, and notwithstanding these conditions they lasted, as I said, up to 20 years, the average life of the 69 ties being 17 years.

I had an opportunity to examine those ties at the end of 7 years. There were 69 ties in the track. The other 5 groups of ties had disappeared. I had occasion to examine those ties again at the end of 14 years, and there was a considerable number of them still in the track, again at the end of 20 years 8 ties remained. Unfortunately, I did not expect to make a report or discuss the matter, and I have not the exact figures in my mind. We found that the Wolhaupter tie-plates under the increasing traffic were cutting down into the ties considerably, and they were ultimately removed, due to this cause. The ties particularly interested me, because they did not broom or break open. That is all.

THE PRESIDENT: I would like to have some further discussion.

MR. ANDREW GIBSON: I would like to ask Mr. Cooper what species of timber were used in their ties between Newton and Kansas City?

MR. S. D. COOPER: Texas pine, red oak, and gum.

MR. ANDREW GIBSON: In what way were those test-tracks set out?

MR. S. D. COOPER: Insofar as the ties that I referred to, the 24,000, those were laid out of face on account of some new double-track work that was being put in at that time, but the test-sections on the Santa Fe are regular test-sections. That is, we take a section and form a test-section, and we keep a record of each tie as it appears in the track for the whole of the test-section, and that was instituted in 1910. In addition to that we inspect all the ties taken out of track, and the outcome of that experience was that we got authority from the chief engineer of the system to put in a system of inspection of all ties removed from the track. So we start out in the spring 2 men, and they go in a continuous circle until the weather stops them, inspecting every tie that is taken out of the track for any cause, and make a report each night to the superintendent and also to our office. At the end of the month the results of that inspection are sent to the superintendent of the division, assistant general manager, general manager and the chief engineer of the system. We have found that in 3 years under which this has been instituted, the number of ties taken out of the track which ought to have been left in the track has been reduced to a very, very large extent.

Mr. Steinmayer and Mr. Angier will tell you about the other experiments.

MR. O. C. STEINMAYER: The reason the Frisco started the experimental sections was in order to determine the length of life we were obtaining from our ties. We find we cannot get this information from the renewal records based on reports from each track-section, as not any great reliance as to accuracy can always be placed on the reports furnished by the section men.

We selected from 2 to 5 miles of track on each operating division, attempting to get tangent track as much as possible, because these particular tests were made with the idea of determining the life of the ties without especial reference to mechanical destruction. An inventory was taken of the ties in each test-section and the condition of these ties has been followed since these test-sections were inaugurated in 1914, by making inspections annually. We can see how the decay—if there is decay—in the creosoted tie progresses, or how mechanical wear is destroying our creosoted tie. The renewals as made in these test-sections are from the general run of ties.

MR. C. F. FORD: On the Chicago, Rock Island & Pacific Railway we attempted to keep a record of all treated ties inserted and removed from track. Also to have all treated ties marked with dating nails. The data for this record was based on reports made by section foremen. After keeping the record for several years, we found that the information received from the foremen was incorrect, also that ties were not being marked with dating nails.

We then decided to select a regular track-section on each division that was representative of conditions on the division, and keep a record of ties inserted and removed on test-sections only. All ties in test-sections are marked with dating nails.

MR. E. O. FAULKNER: I would suggest in making reports of the life of creosoted ties or any other timber in the track, that the quantity of creosote left in should be inserted, because that is a factor in the life of the tie that must be taken into consideration. One road, for instance, will put in 5 lbs. to the cubic foot; another will put in 6 lbs. and others 7 lbs. and 8 lbs.

Now, when you come to take a hundred thousand ties, and take the difference in cost between the amount of creosote used in one case and in another, you should necessarily get a longer life for the larger quantity, and yet possibly not one which corresponds to the extra cost in the amount of creosote used.

I have in mind one of our tests made on the Santa Fe where we had different plants send in representative treatments, and took it for granted that everything was commercially treated; some years afterwards when reports were being made of this test, one treatment stood out remarkably well, and inquiring about it we found the men at the plant, unknown to the officers of the company, had made a special matter of it and treated the ties to such an extent that there was no reason why they should not last long, and they could not have treated them commercially, or put them out under commercial conditions treated that way.

I think in giving results it is essential that treating conditions should be mentioned and taken into consideration with the life.

MR. S. D. COOPER: Mr. Faulkner, I think that is the intention, and I am going to explain that the report in my hand now shows the air, the time, the pressure and the absorption, and it is the intention in getting out this new form that it will embody all the information that can be gotten together and prove of interest, giving an absolute record of the treatment.

THE PRESIDENT: Is there any further discussion, gentlemen? If not, we will accept the report of the Committee as information, with our thanks.

We will now have the report of Committee No. 7-01—Economics, Mr. Crawford, Chairman.

REPORT OF COMMITTEE NO. 7-01—ECONOMICS

To the Members of the American Wood-Preservers' Association:

The instructions to this Committee were to "define the conditions under which the various non-pressure treatments are justified."

It is probable that there is not a single member of the Association who does not agree that as a general rule pressure treatment is more thorough, gives a longer life to the wood, and is more economical than non-pressure treatment. The penetration obtained by pressure is deeper, more uniform, and more subject to the control of the operator. Furthermore, the amount of preservative injected to obtain a given penetration may be varied to suit different requirements. This results in economical use of preservatives. It is possible also by pressure equipment and processes to treat green timber, when seasoned timber is unobtainable, whereas non-pressure processes require thoroughly seasoned wood.

On the other hand, there are innumerable cases where pressure treatment is for some reason either impossible or inadvisable and the wood must be either treated by a non-pressure process, used without treatment of any kind, or replaced by some other structural material. This is especially true in rural construction. Forty-six per cent of all the wood used in this country is used on the farms. This is more than is consumed by any other industry. Much of it is continuously exposed to decay. Pressure treatment is available for but a fraction of one per cent of it. In addition to that used on the farms great quantities of wood are used in other construction where pressure treatment is unobtainable. Unless non-pressure treatment is used on this wood it will be used without treatment.

Under present conditions adequate provision for the distribution of pressure-treated timber in small quantities has not been made. Wood-preserving companies are not as yet organized to handle small business, nor has there been much attempt to encourage the retailers of lumber and other wood products to handle pressure-treated timber. A start has been made by a few companies, and it is now possible in some localities for an individual to buy pressure-treated materials of certain kinds according to his needs. To the majority of the people, however, this privilege is not yet available. So long as this condition exists there is a great need for non-pressure methods of treatment.

To thousands of small consumers, wood-preservation of any kind is unheard of and its benefits are unknown. Your Committee feels that a campaign of education to acquaint all users of structural wood with the possibilities and benefits of wood-preservation would be very much worth while. Much has been done along this line by the Government and by some private agencies but the field is still scarcely touched. The results of such educational work would be of material value in increasing the amount of timber which is pressure-treated, in addition to increasing the use of non-pressure treatment. Furthermore, it would be a material benefit to the nation as a conservation measure. It has been estimated that if all wood used where it is subject to decay were given preservative treatment the annual drain upon our forests would be reduced by an amount greater than the combined annual loss of standing timber by forest fires, insect damage, and disease. The field is, therefore, well worth cultivating.

A word of caution seems advisable, however. The Committee wishes to strongly recommend the use of greater care in such educational and advertising campaigns as may be undertaken. The impression should not be given intentionally or otherwise that non-pressure treatments are as good as pressure treatments. Each preservative and method of treatment must be promoted only to the extent justified by its benefits and limitations. If these precautions are taken, and we believe they will be by every reputable concern, the Committee believes great good will result from such campaigns.

There are three principal methods by which wood can be treated without the use of artificial pressure, namely:

(1) Surface treatments.
    (a) Spraying.
    (b) Brushing.
    (c) Dipping.
(2) Hot and cold bath treatment.
(3) Steeping treatment.

With methods number (1) and (2) coal-tar creosote and similar oil should be used.

With method number (3) water-soluble preservatives, such as zinc chloride, sodium fluoride, and mercuric chloride should be used. In the case of mercuric chloride this is called Kyanizing.

In order that the subsequent discussion may be readily understood, these various processes will be defined.

(1) *Surface treatments.*

(a) *Spraying* consists in applying the oil by means of an air-spray.

(b) *Brushing* consists in applying the oil, preferably hot, to the dry wood by means of a brush. More than one coat should be applied.

(c) *Dipping*, as commonly practiced, consists in submerging the wood in hot oil for 5 to 15 minutes, or even longer.

(2) *Hot and cold bath* treatment consists essentially of the following steps:

(a) The wood is heated in oil at 200° F to 225° F. for one or more hours.

(b) It is then either quickly transferred to a tank of cool oil and allowed to stand several hours, or the heating is discontinued after (a) and the wood and oil allowed to cool together.

(3) *Steeping* consists in submerging the timber in a solution of a water-soluble preservative and allowing it to soak for a period of time, depending upon the size of the sticks. In some cases the soaking period is set at one day for each inch in thickness, and one day in addition to this total.

Poles, posts, ties, construction timbers and lumber have been treated in appreciable quantities by these various processes and tested or put into ordinary service, and in general it has been found that their life is materially increased. Failures have occurred from time to time, in most cases no doubt on account of treating unseasoned timber, improper application of the preservative, or because the treatment was not suited to the use to which the timber was subsequently put. The value of these treatments is likely to be greatly impaired, if not entirely lost, unless thoroughly seasoned timber is used. These failures, however, do not condemn methods of treatment which within their limitations have usually given good results. Nevertheless, the Committee again wishes to emphasize the fact that pressure treatment is the most thorough and the most effective, and the possibility of its use should be very carefully considered before adopting a non-pressure process.

In the opinion of this Committee, non-pressure treatment should be adopted only when it is apparent that the added life which might be obtained by pressure treatment is not sufficient to offset the additional cost of the treatment, or when it is practically impossible to obtain pressure-treated timber. Specific cases in which non-pressure treatments are likely to be advisable are as follows:

(1) For treating timbers and lumber used in building and car construction and repair work which must be framed at the

building site, or which are used in such small quantities that it is impracticable to send them away for pressure treatment.

Of the various non-pressure treatments possible, hot and cold bath treatment with creosote will generally be most effective. When apparatus for this process is not available, surface treatments may be used.

For places where the odor or color of creosote would be objectionable, water-soluble preservatives applied by the steeping process may be desirable. These preservatives are, of course, not suitable where the wood is likely to be wet frequently.

(2) For timbers used in interior construction where the ends are placed on concrete, brick, or stone foundations, and only the ends are subject to decay, and for any other timbers where only points of contact with wood or other material are likely to decay prematurely.

Surface treatments are usually the only methods which can be used in such places, but great benefit at little expense can be expected.

(3) For fence posts under conditions which make pressure treatment out of the question, hot and cold bath creosote treatment of the butts is recommended, together with a hot or cold bath treatment of the tops. Surface treatments are not as effective as hot and cold bath treatment, and their use on posts is seldom to be recommended.

(4) For telegraph and telephone poles of durable species, from which experience has demonstrated good service may be expected when butt treated, the hot and cold bath treatment is recommended. Butt treatment under pressure would probably be much more effective, but the apparatus for treating by this method is so far not available. Surface treating the butts of poles of durable species with creosote is usually also sufficiently effective to more than pay for the cost of treatment and may be used to good advantage where conditions prevent more thorough treatment.

Poles of nondurable species, especially for use in the southern states should be treated throughout their entire length by a pressure process.

(5) In general, the hot and cold bath treatment is the nearest substitute for pressure treatment, and is to be recommended in preference to the more superficial treatments. Dipping, spraying, and brush treatments are more superficial than the hot and cold bath process and generally result in only a slight

penetration of oil. They are, therefore, most suitable for timbers not subjected to mechanical wear or serious checking. The steeping process due to the long soaking period approaches the hot and cold bath process in the matter of penetration. Since water-soluble preservatives are used, the treated wood has the limitations and advantages common to these preservatives.

The Committee offers the foregoing as information only, and desires that it receive thorough discussion. We recommend that the Committee be continued for another year, in order that it may digest the discussion at this meeting, and formulate specific recommendations for the MANUAL.

CARL G. CRAWFORD, *Chairman*
A. W. ARMSTRONG
K. C. BARTH
G. M. HUNT
H. S. SACKETT
L. B. SHIPLEY
H. VON SCHRENK

THE PRESIDENT: Now that we have heard the Committee's Report we are ready for discussion.

MR. R. F. HOSFORD: Mr. President, there are a few points I want to make with respect to matters in the report; first, as regards the question of the necessity of seasoning. We have 2 experiments in which the open-tank, or hot and cold bath method was applied to both seasoned and green timber. In one the poles have been placed for about 15 years. We have a 14-year record of them, 94.5% of the seasoned poles are perfectly sound and not changed, and 93% of the green were in the same condition—nothing to choose as yet between the green and the seasoned. In another case, seasoned and green cedar poles were treated at about the same time, but not set in line until a period of 4 years had elapsed. Reports covering the treatment were to the effect that the treatment of the green cedar did not proceed satisfactorily; nevertheless, the 10-year inspection just made shows that the seasoned poles are in 100% perfect condition, and 95% of the green poles—again very little difference.

Another point that has been noticed in connection with these poles is that apparently the open-tank treatment had a certain seasoning effect, that is, we find perhaps a check which may start to run down a pole, but peters out when the treated section is reached. That has not only been observed in these instances, but others have spoken to me about noticing the same thing. So that I rather question the conclusion that such treatment cannot be applied to green timber. It may be more economical for other reasons to apply it to seasoned timber, but it is not impossible to apply it to green poles.

Another point, and this is something that I have studied by experiments, is that if we carry along the open-tank treatment on timbers to which we have also applied the cylinder-pressure treatment, we find that we get about the same penetration. For instance, southern pine with considerable sap, we have just for trial treated pieces in the open-tank and obtained practically as good a depth as we would by cylinder-pressure methods. I am inclined to believe, therefore, that there is no fundamental difference in the results obtainable by the 2 methods.

It seems to me also that the report might be improved along the economic side and give more credit to the lighter and more superficial treatments. There are a great many cases where the maximum life can be obtained from such an experiment as the chestnut pole case referred to above, which now looks to me like a 20-year increase in life. If you spend a dollar to get it you may not be able always to utilize this big gain and get the dollar back. Now all of these treatments are dependent on getting more than the dollar back, so in many cases such a superficial treatment as will bring the dollar back has to be preferred to the more expensive one which may not do so.

THE PRESIDENT: Mr. Hosford brought up a very interesting point that some day we are going to dig into,—the apparent ability of creosote oil to prevent checking; the same thing Mr. Kirkbride said; that these 20-year old ties did not seem to broom out. We do not know very much about this particular function of the oil yet, but we do know there is a very decided something in creosote oil which helps to keep the surface of the timber solid. I would like to have some further discussion.

MR. J. H. WATERMAN: Mr. Chairman, do I understand you to state that creosote oil will not prevent timber from checking?

THE PRESIDENT: No, sir.

MR. J. H. WATERMAN: That is the way I understood it, and I am afraid there are a lot more who understood it that way. I am here to tell you that creosote oil properly applied will prevent timber from checking.

THE PRESIDENT: That is exactly what I tried to say.

MR. J. H. WATERMAN: I misunderstood you. I thought we spoke the same language coming from the same State. [*Laughter.*]

THE PRESIDENT: Well, in other words, Mr. Hosford noticed that the checks ran out when they got into the oil treatment; Mr. Kirkbride noticed the same thing on the ties; I have noticed the same thing, and you have noticed the same thing.

MR. J. H. WATERMAN: And I know it prevents checking.

THE PRESIDENT: But do you know why?

MR. J. H. WATERMAN: I know why. Why does one man go out and husk corn in his bare hands and they never check while another man husks corn and his hands check? One man is full of oil and the oil boils out and softens his hands and they never check; the other fellow has a dry hand and it cracks—I learned that when I was a boy on the farm. [*Applause.*]

THE PRESIDENT: Is there any further discussion?

MR. CARL G. CRAWFORD: In reply to some of the points brought out by Mr. Hosford it was not the sense of this Committee that you cannot treat green timber by the open-tank process, but that much better work can be done on seasoned timber. It does not require nearly so much care in doing the work, nor does it offer the opportunity for poor work being done. In making recommendations the Committee feels that the only safe course to pursue is to recommend that the timber be well seasoned. For the other non-pressure methods mentioned in the report, seasoned timber should be used.

As I understood the latter part of Mr. Hosford's remarks, they were in line with the recommendations contained in this report.

MR. WALTER BUEHLER: I think the Committee has done absolutely the right thing to point out the necessity for seasoning the timber when the non-pressure process is to be used. We do not want to forget this point: Mr. Hosford has at his beck and call an organization that can inspect the treatment and see that every care and precaution are taken so that a good treatment is the result. The non-pressure process on the other hand will be used, and should be used, more universally, and will, therefore, be used by users of not the experience of the organization that Mr. Hosford has, and it is, therefore, well to point out that seasoned timber shall be used, because in the hands of the inexperienced, disastrous results might be obtained from the use of green timber.

THE PRESIDENT: Is there further discussion? If not we will accept the report of the Committee as information. Thank you.

We will ask Mr. Angier to read the "Treatment of Mine Timbers," by L. W. Conrad.

TREATMENT OF MINE TIMBER.

By L. W. Conrad.

Geological conditions in the anthracite coal fields make necessary the use of a tremendous amount of timber for mine supports, etc. Several factors make the life of this timber much shorter than if used outside the mines under different conditions.

There is a constant stress on mine timber, and at times the squeezing action or subsidence is so great that many of the supports are crushed or broken beyond further use or repair. Then again the damp, warm atmosphere in certain parts of the mines is especially favorable to the rotting of wood, by reason of the growth of such organisms as fungi. Timber in such places furnishes a number of specimens of wood-destroying fungi which are not small factors in the destruction of timber used inside the mines.

The choice native timber, or more durable species, such as Pennsylvania yellow (pitch) pine and white oak are undoubtedly preferable, both as to strength and durability, but such timbers are becoming a thing of the past. At present the mining industry is compelled to use black oak and red oak and principally loblolly pine shipped from Maryland, Virginia and North Carolina.

The average life of such timber is about 3 years. Not only is this timber high in price and short in life, but there is to be added the cost of labor in replacing timber broken or decayed. This labor cost is approximately equal to one-half the cost of new untreated timber.

While there are some places in the mines that will likely be abandoned before the life of the timber is at an end, yet much timber in the main haulage and airways must be in service for practically the entire life of the mine. Hence any method of treatment that will especially resist decay, and thereby prolong the life of timber, will mean a considerable saving in the operation of any mine. Care should be exercised, however, to place treated timber in parts of the mines where crush or squeeze are the least likely to occur as no treatment would be economical when timber is broken after being in use a short time. The factor of breakage, of course, may not be as serious in other mining industries as it seems to be in the anthracite field.

During the years 1906, 1907 and 1908 the Philadelphia & Reading Coal & Iron Company conducted experiments to determine the relative value of creosote, gas-tar oil and zinc chloride, all of which were used in the open-tank method. It was, therefore, necessary to air-dry or season the timber 60 or 90 days in order to get the desired impregnation. This experimental work demonstrated the value of timber treated, and a small pressure plant was accordingly erected at Silver Creek colliery, New Philadelphia, Pa. With the pressure plant it, of course, was possible to treat the timber more economically as well as more efficiently. For a short time creosote and gas-tar oil were used with very good preservative results, but because of the possibility of fire it was concluded the presence of any kind of oil would likely increase the difficulties in fighting a mine fire.

Beginning with 1908 zinc chloride was used in about a 4% solution, and by injecting about ½ lb. of zinc chloride in solution per cubic foot of the timber we found such treatment successfully resisted decay. Zinc chloride was used until the latter part of 1915 when it was rather difficult to purchase an adequate supply at a reasonable price. Upon the advice of our chemist we began the use of sodium fluoride which we found readily obtainable in powder form in commercial quantities. Sodium fluoride is sparingly soluble in water, but we began its use with a 3% solution, having a specific gravity of 1.03 at 60° F. With both zinc chloride and sodium fluoride we always aimed to get a thorough penetration.

Sodium fluoride can now be purchased from a number of firms, but there is not a great deal of information as to just what purity of sodium fluoride is desirable for the treatment of mine timber. The sodium fluoride which we purchased has generally shown an actual sodium fluoride content of over 90%, although we received samples from various firms that showed a variation in sodium fluoride content of 78% to 95%.

The general impurities in commercial sodium fluoride are sodium silico-fluoride or sodium fluosilicate, sodium sulphate, and insoluble matter such as silica or clay. We are not prepared to discuss the advantages or disadvantages of these impurities.

We have a specification as follows:

> The material should contain at least 94% actual sodium fluoride, other salts not to exceed 5%, matter insoluble in water not to exceed 0.5%; and sodium carbonate not over 1%; the material should be free from acid and contain as little water as possible.

During the past 2 years, because of war conditions and the attending difficulties in procuring a regular supply of timber and preservatives, very little work has been done along this line, but we are now accumulating a large stock of suitable timber which will be treated with sodium fluoride in the very near future.

Several hundred sets, or about 75% of the timber treated with coal-tar creosote during 1907 and 1908 were placed in a gangway that later was closed because of mining conditions that developed after the timbers were placed. However, a sufficient number of sets so treated and placed in other sections of the mines show an increased life of 10 years. The sets treated with water-gas-tar oil have also added to the life of untreated timber, but do not show results equal to creosote.

The timber treated with sodium fluoride (0.3 lb. salt per cubic foot) in the mines the past 5 years is still in good condition. We also have experimental timber treated with zinc chloride (0.5 lb. salt per cubic foot) in use the past 10 years and still in serviceable condition. Both of the above treatments show a considerably increased life over untreated timber and at an added cost of about 25% to 30%. In fact, the experimental timbers treated with the various preservatives cover a total of several thousand sets which have conclusively proven that it is possible to greatly increase the life of timber used in the mines.

The President: Gentlemen, would you care to discuss this paper? The use of sodium fluoride particularly in mines looks like a very good proposition. If there is no discussion we will ask the Secretary to read the report of Committees No. 7-3-1 and 2.

REPORT OF COMMITTEES NO. 7-3-1 AND 2-FLOORING AND PAVING

To the Members of the American Wood-Preservers' Association:

Your Committee on Flooring and Paving has no report for the consideration of this convention. The Committee was late in organizing, and can merely report progress.

The Sub-Committee on Flooring has been in conference with the idea of developing standard methods of flooring which will embody the latest improved methods of construction and installation. The subject, however, is so important that it was decided by the Committee that it would be better to defer action until more consideration could be given the subject.

The Sub-Committee on Paving has considered a number of problems in connection with street paving, car-track construction, and bridge floors, but, unfortunately, they were unable to arrange for a meeting of the various members.

The work outlined for the present Committee should be continued during the coming year. This work may be outlined as follows:

Sub-Committee on Flooring: The development of standard methods of flooring.

Sub-Committee on Paving: The development of standard methods of paving, giving special attention to bridge and car-track paving.

Your Committee believes that better progress can be obtained with the responsibility resting upon a single chairman, and recommends further that the membership of the Committees be decided upon early in the season, and that part of the old membership be retained each year to assist in organizing the work for the new year.

L. T. ERICKSON, *Chairman, Committee No. 7-8.*

SUB-COMMITTEE NO. 1—FLOORING.

THOMAS RODD, JR., *Chairman,*
C. L. HUMPHREYS,
L. P. KIMBALL,
A. E. LARKIN,
E. J. STOCKING.

SUB-COMMITTEE NO. 2—PAVING

E. R. DUTTON, *Chairman,*
T. P. JOHNSTON,
F. G. MARRIOTT,
K. J. SCHMAELZLE,
ALBERT SCHWARTZ.

THE PRESIDENT: If there is no objection we will accept the report of the Committees as information, and refer the recommendation to the Executive Committee.

We will ask that the Secretary read the last paper for the afternoon, "Creosoted Lumber in Connection With the Farm and Ranch," by E. A. Lindsley.

CREOSOTED LUMBER IN CONNECTION WITH THE FARM AND RANCH.

By E. A. Lindsley.

A successful ranchman or farmer will tell you that one of the first requisites to success is the proper protection for tools, crops and animals. He will also tell you that the features of permanence, durability and sanitation are the most important ones to be considered.

Creosoted wood blocks, timbers and posts may be designed to economically meet all requirements of modern farm or ranch construction. They are being used extensively for such purposes throughout the United States and Canada, for flooring, stables, chicken houses, garages, piggeries, machine sheds, etc.; for paving exterior driveways and bridges; for sills, joists, etc. in all buildings; for silos and for fence posts. These materials are thoroughly treated against decay and are rendered sanitary and antiseptic by the creosoting process.

The qualities of permanence and sanitation alone make creosoted materials ideal for use in modern farm buildings.

FLOORS.—Perhaps of greatest importance to the farmer or ranchman is the creosoted wood block for use as stable floors. Such floors are very highly recommended by prominent dairymen, veterinarians and breeders of valuable stock throughout America.

In these days of scientific stock raising, when a horse, cow or pig cannot be purchased for the low prices that once prevailed, and when the price of a single animal is often more than the price of a sheltering barn, it is obvious that the best is none too good for the comfort and health of the animal.

From the standpoint of health and sanitation, the floor is the most important part of the stable, since it is there that germ-carrying diseases live and propagate. Veterinarians and bacteriologists claim that the hoof and mouth disease and hog cholera are best combated by cleanliness and by such precautionary measures as the use of sanitary flooring. For instance, the hoof and mouth disease is spread by germs. When live-stock are affected by these germs they naturally leave some of the germs on the floor, causing infection of other animals that might use the same stalls or pens, or in some other way come into contact with the germs. Infection is possible in so many ways that any chance to retard the disease should not be overlooked.

Health and sanitation in barns and stables by means of the use of creosoted block floors are made possible because of the ease with which the floors may be cleaned, and because of the high germicidal properties of the antiseptic oil with which the blocks are treated.

The wood used in the manufacture of these blocks is carefully selected, injected with a highly antiseptic preservative oil, forced into the interior of the wood in treating process by hydraulic pressure. This highly antiseptic preservative oil is obtained from the fractional distillation of coal tar, some of the components of which are anthracine, napthaline, etc., all of which are highly germicidal.

Creosoted block floors, therefore, reduce the virulence of infectious material on the floor, and, although the causes for infection may be many, the use of a clean, sanitary floor is highly desirable to secure better conditions of health and sanitation.

The advantages of creosoted wood block floors for stables, etc., may be summed up as follows:

1.—DURABILITY.—All the wear comes on the end of the grain, the same as upon a wood mallet. Tests have shown that a creosoted block will outwear brick, concrete, oak plank or stone. After the top fibers of the block are compressed there will be practically no wear. Creosote oil, with which the blocks are treated, thoroughly preserves them from decay.

2.—SANITATION.—They have a smooth surface, are non-absorbent and easily cleansed. They are treated with an antiseptic oil that destroys all germs and vermin that commonly infect the average barn floor.

3.—WARMTH.—They are non-conductors of heat, and, as a result, are warm and restful, retaining all the warmth that is produced by the animal's body. This effects a considerable saving in the amount of bedding that is necessary, as compared with a cold, hard floor.

4.—EASY UNDERFOOT.—Their resilience prevents sore hoofs, stiff joints, big knees, rheumatism, etc.

5.—NON-SLIPPERY.—They may be laid so as to give a good foothold for animals under wet or dry conditions. They may be laid on grades and at the same time eliminate the possibility of injury from slipping.

6.—LOW MAINTENANCE.—When properly laid they will outlast the stable, barn or pen in which they may be installed, with no repairs or maintenance cost.

7.—FIRE RESISTANCE.—The creosoted block will resist fire greater than an untreated wooden floor. This statement has been repeatedly proven by such instances as the following: Eleven farm buildings owned by the Knudsen Dairy, near Toledo, Ohio, recently burned. The heat was so intense that concrete floors were broken up and disintegrated. The wood-block floors installed in the modern dairy barn were practically unaffected.

The use of creosoted wood blocks for farm buildings are not an experiment. They have been subjected to years of hard usage in dairy-barns, horse-stables, bull-pens, calf-pens, hog-houses, etc., and have successfully withstood the test of time. Leading scientific farmers throughout America recommend them without reservation.

Dairy-barn flooring has been a very serious problem up to within the last few years. Nature never intended the dairy cow to stand on hard, unyielding floors day after day and night after night; nature never intended the dairy cow to lie down on damp, cold concrete to rest her warm, sensitive udder upon its cold surface. Concrete is not a suitable material for stables; it is hard, cold, damp and uncomfortable. An uncomfortable cow cannot yield her maximum of milk. A floor of wood plank, though easy under foot, will soon rot and require renewal.

Sanitation plays a most important part in successful hog-raising. For the hog-barns, therefore, particularly in farrowing time, the warmth and comfort of a creosoted block floor will prove invaluable. The farrowing sows need a dry, warm floor on which to lie, and the little pigs need a warm floor as much more than their mother.

A creosoted-block floor is germproof, acts as a fly and vermin repellant and is one of the biggest aids possible to sanitation in hog-houses.

Hogs lying on a cold concrete floor are very apt to get rheumatism. The concrete draws the heat from the body and the hogs become chilled through in a very short time.

CREOSOTED LUMBER IN CHICKEN-HOUSES.—The advantage of creosoted lumber for use in hen-houses are apparent. Warmth and the absence of lice, nits, etc., are some of the most important features in successful poultry raising, with subsequent satisfactory egg-production.

CREOSOTED STAVES.—The use of creosoted-wood staves for silos has increased by leaps and bounds since authoritative analyses have been made of ensilage in contact with these staves. It was found that, although the ensilage contained a certain amount of creosote, it does not prove injurious to the health or appetite of the cattle. Government bulletins have been issued confirming the above. The use of creosoted timbers in silos greatly increases the life of the wood, because of the decay-resisting qualities of the preserved timbers.

CREOSOTED POSTS.—The day is past when farmers may be able to either go to their own wood-lot for posts, or purchase from a local dealer at a nominal sum. Furthermore, labor is expensive and scarce. These facts prove that the successful, thinking farmer or ranchman will, in the future, use creosoted posts that have been preserved against decay, thus effecting a saving of considerable proportion on his fence maintenance.

GENERAL USE OF CREOSOTED LUMBER.—There are many places on the farm or ranch where creosoted lumber should be used. The time and expense of repairs could be greatly reduced if treated lumber were used as sills and joists of all buildings, for scale pits, platforms, on bridges, corrals, water conduits, tanks, etc.

The use of creosoted lumber has increased very rapidly, and the saving thus effected more than balances the initial first cost. The time has long since arrived when the growing scarcity and high price of lumber and structural materials must be offset by increasing its longevity. The successful farmer or ranchman does not hesitate to use paint to improve the appearance of his property. The day has arrived when creosoted lumber must be used just as judiciously for all places where heretofore untreated wood did not give the requisite degree of permanence.

THE PRESIDENT: Gentlemen, we have enjoyed this paper very much, and if you can add anything that has been overlooked we would be glad to have you do so. If not, we will stand adjourned and meet in this room at 6:30 o'clock for dinner. Be prompt, please, and this evening we have the marine piling report, which is very important.

TUESDAY EVENING SESSION

January 25, 1921.

THE PRESIDENT: The meeting will please come to order. We would like to have the report of the Marine Piling Committee.

REPORT ON THE SAN FRANCISCO BAY MARINE PILING SURVEY

INTRODUCTORY

By E. M. Blake

Early in the year 1914, the activity of marine borers was noticed in the dykes of the Mare Island Navy Yard, at the upper extremity of San Pablo Bay, which is the northern arm of San Francisco Bay, as well as at two nearby points on the east shore of that bay. One of the latter was a dock between Crockett and Vallejo Junction and the other a dock at Oleum, a mile or so south of Crockett. Sporadic attacks of marine borers are reported to have been observed in that region at isolated times running as far back as 1870, although no certainly authentic records of them could be secured. In any case, however, these attacks were of short duration and did no serious damage. For many years previous to the attack of 1914 the unusual facilities offered around the shores of San Pablo Bay and the waterfront above that bay, including Carquinez Straits, Suisun Bay, and the lower course of the Sacramento River, had attracted many large industries. The waterfront structures erected by these varied industries were all built on untreated piling, because of the absence of marine borer activity in those waters and the belief that the fresh water discharged into San Pablo Bay from the combined flows of the Sacramento and San Joaquin Rivers would probably prevent any invasion of San Pablo Bay by salt water, which would carry with it the various forms of marine borers.

The attack of 1914 appeared to be sporadic, like the earlier ones. But in 1917 attacks by the same shipworm, which was identified as a teredo, again appeared at and near Mare Island, and during the following years spread very rapidly and increased in severity. In the latter part of 1919 the attacks had progressed to such an extent that parts of waterfront structures and in some cases whole docks began to fail (pl. 1, fig. 1). In 1920 these failures assumed such proportions and became of such frequent occurrence that the critical nature of the local situation was brought to the attention of the officials of the American Wood-Preservers' Association on June 16, 1920 (pl. 1, figs. 2 and 3; pl. 2). As a result, a special committee was appointed on July 22, 1920, to study the marine piling problem in San Francisco Bay, with instructions to report at the Seventeenth Annual Meeting of the Association at San Francisco in January, 1921. The committee so appointed was enlarged from time to time as new local interests became enlisted, but began its active work late in July, 1920.

Shortly before June 16, 1920, but practically coincident with the above action, the Forest Products Laboratory of the U. S. Forest Service at Madison, Wis., had proposed a plan for the study of the marine piling problem covering the entire coastal waters of the continental United States. During preceding years the Laboratory, as well as other agencies, had made various local studies of the activities of marine borers and the methods of their control. One such project was initiated in 1910–1911 by the Forest Products Laboratory and the California District of the Forest Service, in coöperation with the University of California through Professor Charles A. Kofoid for the biological aspects of the problem. It had in view a study covering the harbors of California. Two phases of the project were carried out, involving the experimental testing in the harbors of San Francisco and San Diego of various species of wood, methods of protection, and treatment with different fractions of coal tar creosote. These studies, however, had been scattered and more or less fragmentary, and the Laboratory decided that it was now desirable to bring the results of all these studies together and thoroughly investigate the entire problem, including the engineering, biological and chemical phases of the subject.

In this situation, it was the logical step to unite both proposals, and the San Francisco Bay Marine Piling Survey became, therefore, the first unit of the proposed nation-wide program of the Forest Products Laboratory, under joint coöperation with the American Wood-Preservers' Association.

Authority for Investigation

The San Francisco Bay Marine Piling Survey was definitely begun in September, 1920, as a coöperative undertaking between the American Wood-Preservers' Association, acting through a special committee appointed for that purpose as above stated, and designated as the San Francisco Bay Marine Piling Committee; the U. S. Forest Service, acting through the Forest Products Laboratory of Madison, Wis., and through the California District of the Forest Service at San Francisco; and the University of California, acting through the Department of Zoology. The authority and instructions for making the survey were granted by the bodies above mentioned and the investigation was made possible through the generosity of interested parties in and around San Francisco Bay who contributed the funds to meet the necessary expenditures.

Organization

The personnel of the San Francisco Bay Marine Piling Committee is as follows:

FRANK D. MATTOS, Manager Treating Plants, Southern Pacific Company, Oakland, Calif., Chairman.

C. L. HILL, in Charge Office of Forest Products, U. S. Forest Service, San Francisco, Executive Officer.

E. M. BLAKE,* San Francisco, Production Engineer, Charles R. McCormick & Co. and the St. Helens Creosoting Company, Secretary and Fiscal Agent.

Dr. **CHARLES A. KOFOID**, Professor of Zoology and Assistant Director of the Scripps Institution for Biological Research, University of California, Berkeley, Calif.

A. M. BAXTER, J. H. Baxter & Co., San Francisco, Agents for Pacific Creosoting Co. and Colman Creosoting Works, Seattle.

A. A. BROWN, Construction Engineer, California and Hawaiian Sugar Refining Co., Crockett, Calif.

H. J. BRUNNIER, Consulting Engineer, San Francisco.

CARLOS E. CORTES, Construction Engineer, Shell Company of California, Martinez, Calif.

C. E. GRUNSKY, Consulting Engineer, San Francisco (Honorary Member).

Lieut. **ALLEN HOAR**, Corps of Civil Engineers, U. S. Navy, Mare Island Navy Yard (Honorary Member).

Capt. **C. S. JARVIS**, Corps of Engineers, U. S. Army, Fort Mason, San Francisco† (Honorary Member).

L. D. JURS, Chief Engineer, Associated Oil Company, San Francisco.

W. H. KIRKBRIDE, Engineer of M. of W. & S., Southern Pacific Company, San Francisco.

Lieut. **C. L. MACRAE**, Corps of Civil Engineers, U. S. Navy, Mare Island Navy Yard (Honorary Member).

FRED H. MUHS, Vice President, San Francisco Bridge Company, San Francisco.

RALPH RAWSON, Consulting Timber Engineer, Portland, Ore.

T. G. TOWNSEND, Engineer in Forest Products, Forest Products Laboratory.

O. R. WEST, Asst. Engineer, Atchison, Topeka & Santa Fe Ry., San Francisco.

F. G. WHITE, Chief Engineer, Board of State Harbor Commissioners, San Francisco.

J. W. WILLIAMS, Chief Engineer, Northwestern Pacific Railroad, San Francisco.

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* Deceased January 12, 1921.

† Since transferred to Camp Lewis, Washington.

All of the above, with the exception of the honorary members, are members of the American Wood-Preservers' Association.

In the conduct of the work the Forest Products Laboratory of the U. S. Forest Service is represented by George M. Hunt, in charge Section of Wood Preservation, and T. G. Townsend.

The California District of the U. S. Forest Service is represented by C. L. Hill.

The University of California is represented by Professor Charles A. Kofoid.

In addition to the members of the Committee and the interests directly represented by them, many others have assisted actively in the work, either by financial contribution or through furnishing the Committee with information and giving personal service in some phase of the survey. The names of the contributors to the fund for the survey will be found in Appendix A. To all such the Committee desires to express its full appreciation and acknowledge its obligation. Without the financial support given by the contributors to the fund, it is probable that the study of the marine piling problem in San Francisco Bay at this particular critical period would have been very much limited in its scope. Seldom, it is believed, has a coöperative scientific investigation of such magnitude as this one received a greater or more cordial support. Special acknowledgment is made of the courtesies extended by the U. S. Navy, through the Commandant of the Mare Island Navy Yard, and by the U. S. Army, through the Commanding Officer at Fort Winfield Scott, in the furnishing of boats and assistance for the investigation. The following have also given special assistance to the work of the survey:

F. W. Camp, Contractor, San Francisco.
H. O. Demeritt, San Francisco-Oakland Terminal Railways, Oakland.
W. W. DeWinton and W. J. Hunter, Moore Shipbuilding Company, Oakland.
H. K. Heck, Harbor Engineer, City of Oakland.
Howard C. Holmes, Consulting Engineer, San Francisco.
C. M. Mardel and W. T. Richards, San Francisco-Sacramento Railroad, Oakland.
The Monticello Steamship Company, Vallejo.
The Petaluma & Santa Rosa Railroad, Petaluma.
San Francisco, Napa & Calistoga Railroad, Napa.
H. L. Smith, Union Oil Company, Oleum.
Thos. B. Swift and O. K. Smith, Mountain Copper Company, Martinez.

Objects and Division of the Work

The objects of the survey were to determine the extent of the damage from marine borers in San Francisco Bay, especially that of excessive severity which has occurred within the last three years in the northern portion of the bay; to determine the present distribution of the several marine borers and as much of their past history in the bay as it was possible to learn; to increase the present knowledge of the dissemination, growth and habits of the borers; to study the factors influencing the rate of attack and amount of damage from them, including the effect of climate and river discharge upon the salinity conditions in the bay; to throw more light upon the effectiveness, both in physical life and economic advantage, of the various methods of protecting wooden piling, and of the substitutes for it, together with the best methods of construction which have been developed; and to collect data on the relative costs of the different methods of protection and construction.

In order to accomplish these objects, the investigation was organized along three distinct lines:

1. *Hydrographic Phase.* This phase had to do with the effect of climatic conditions and river discharge upon the salinity of the water in the northern arm of San Francisco Bay and its tributaries. This part of the survey was entrusted to Mr. C. E. Grunsky and Captain C. S. Jarvis, whose familiarity with the conditions and problems of the Sacramento and San Joaquin Rivers and their watersheds has made possible this valuable addition to the report of the Committee, with its vital bearing upon the marine piling problems encountered in the upper bay.

2. *Biological Phase.* This phase had to do with the present distribution of marine borers, their past history, their dissemination, growth, and habits, and the factors influencing their rate of attack and the resulting damage. This part of the survey was entrusted to Professor Chas. A. Kofoid, and through his coöperation the Committee is enabled to present in this report what is believed to be one of the most valuable contributions to the biological knowledge of marine borers so far made.

3. *Engineering Phase.* This phase had to do with the design, construction, maintenance and repair, with their costs, of marine waterfront structures already attacked by or subject to the attack of marine borers, and covered an investigation of many different methods of protection against such attacks. During the most important part of this phase of the survey, the Committee was fortunate in having the personal assistance of Mr. George M. Hunt of the Forest Products Laboratory at Madison, Wisconsin.

Development of the Survey

A questionaire was first sent out to the owners of all important waterfront structures in San Francisco Bay and its tributaries, the returns from which not only furnished valuable information to the Committee but also helped in planning the various stages of the field investigations. On account of the peculiar problems involved in the biological phase of the study, it was seen that certain definitely outlined experimental work would be necessary. The importance of uniformity in that work and the fact that much of it would have to be done by widely scattered coöperators made necessary the careful preparation by the Committee of a manual of instructions covering the methods to be followed in the determination of salinity, in the placing of test specimens, in the preparation and preservation of biological and other specimen material and in the collection and submission of reports and photographs. The form of the questionaire will be found in Appendix B, and the instructions in Appendix C.

In the work of the survey engineers, some time was at first spent in trips of a reconnaissance nature. Attention was then turned to the areas most essential to the purposes of the survey. Arrangements were made wherever possible for the pulling of piles and every opportunity possible was taken to witness such pulling where alterations or repairs were in progress. Meanwhile an attempt was made to gather all the information available from the files of coöperating companies and other agencies, both public and private.

As the work progressed, however, its evident magnitude increased so rapidly that it became apparent that only a progress report could be attempted in the short time available. Much, therefore, remains to be done, as will be indicated in the recommendations for continuance of the study to be found at the end of the Engineering section of the report.

Geographical Setting of the Problem

The name ''San Francisco Bay'' is technically applied only to the larger and more important southern arm of the body of water which has its connection with the Pacific Ocean through the Golden Gate. The name is more often used than any other, however, when it is desired to indicate the entire body of water. This larger bay has its longer dimensions closely parallel to the seacoast. It is 52 statute miles in its greatest length in a single direction, and has a maximum width of slightly under 12 miles. The outlet through the Golden Gate is at a point about three-fifths of the total length of the bay from south to north. At a point about one-half of the remaining distance north from the Golden Gate the width of the bay is reduced to a little over one mile, and that point marks the division between San Francisco Bay proper and the upper area known as San Pablo Bay.

At the eastern end of San Pablo Bay there enters a channel known as Carquinez Straits, through which the combined flow of the Sacramento and San Joaquin Rivers is discharged into San Pablo Bay. The Carquinez Straits are from seven to eight miles in length and above them is a large area of water composed of many tidal flats and salt marshes known as Suisun Bay. At a point about 18 miles above Carquinez Straits is the junction of the Sacramento and San Joaquin Rivers. Above that junction both rivers meander in constantly dividing and re-uniting channels through an extensive delta region of islands, sloughs and marshes.

Reference to the map which accompanies this report will make clear the geographical relations which have been described.

Historical

San Francisco Bay, in common with most ocean harbors, has been subject to marine borer activity ever since records have been kept in this respect, although tradition says that the ship worm was not known there in Spanish days and did not become a menace until after the large shipping increase in the port which followed the gold rush of 1849. The damage caused by marine borers became a serious problem, however, not many years afterwards.

In a paper by James McKeon, appearing in the official Proceedings of the Pacific Coast Railway Club for 1904, it is stated that in 1897 *Limnoria* had not yet made its appearance in Humboldt Bay, and in 1900 they were doing but little damage in Seattle and Tacoma. ''In 1896,'' continues Mr. McKeon, ''Mr. Marsden Manson, an engineer of high standing, stated in a newspaper article that the damage wrought by *Teredo* and *Limnoria* in the harbor of San Francisco alone amounted to $250,000.'' Speaking of the old Fremont street wharf, he says, ''On Saturday, June 25, 1892, the ship 'Cyrus Wakefield,' moored to this wharf in a light storm, towed a portion of this structure into the bay. An examination showed that the piles were entirely destroyed by *Teredo.*''

In the early engineering reports of this region similar references are frequently made to the ''teredo.'' It is unlikely, however, that the earlier writers had any technical knowledge of the different kinds of borers. So far as biologists know, the only shipworm observed in these waters prior to 1914 was the *Xylotrya.* This borer, together with the *Limnoria,* were the ones which had caused the principal damage in San Francisco Bay prior to that time.

Destruction from marine borers in San Francisco Bay has been most active in the regions nearest the Golden Gate, where unprotected timber is destroyed within a few months. Destruction is nearly as rapid southward around the San Francisco waterfront. On the Oakland side destruction is somewhat less rapid, unprotected piling lasting from 18 months to three years. In the Oakland estuary the activity of *Limnoria* is greater than that of the *Xylotrya* and piling may be destroyed in as short a time as six months (pl. 3). From South San Francisco on the western side of the bay and Alameda on the eastern there is, southward, a vast stretch of shoreline enclosing the southern end of the bay, which is its largest area. Industrial activity of a kind which requires waterfront construction is very scanty, however, in this southern area. There are, therefore, few structures from which the activity of borers may be measured. On account of the much greater industrial importance of the northern areas and the very short time available, a complete study of the southern area was not attempted. Some investigations, however, were carried as far south as the Dumbarton cutoff. At the plant of the Schaw-Batcher Company in South San Francisco, there was found an attack by a form of teredo not observed during this survey in the northern part of the bay area. This will be discussed in the biological section of the report.

In the northern area, including the lower course of the Sacramento River, Suisun Bay, Carquinez Straits and the adjacent portions of San Pablo Bay, many of the piling structures, although built wholly of untreated wood, had stood from 30 to 40 years. The destruction there since 1917 by the teredo has been swift and unusually severe. Every waterfront structure as far upstream as Antioch has been attacked by the *Teredo*. Following is a list of the more important structures which have shown the effect of the most serious and concentrated attack by marine borers in that area during the last two years:

Hercules
    Fernandez Wharf.
    Hercules Powder Co.
Rodeo
    6-Minute Ferry.
Oleum
    Union Oil Co.
Selby
    American Smelters & Securities Co.
Vallejo Junction
    Southern Pacific Railroad ferry.
Black Point
    Northwestern Pacific Railroad bridge.
    State Highway bridge.
Mare Island
    U. S. Navy structures: dykes (one 8000 feet long), docks, and causeway (3500 feet long).

Napa Junction
  Associated Oil Co.
Vallejo
  Ferry to Navy Yard.
  Southern Pacific Railroad ferry.
  San Francisco, Napa & Calistoga Railroad.
  Monticello Steamship Co.
South Vallejo
  Ferry to Rodeo.
  Southern Pacific Railroad ferry.
  Sperry Flour Co.
  6-Minute Ferry to Crockett.
Crockett
  Port Costa Lumber Co.
  Matson Navigation Co.
  6-minute Ferry.
  California-Hawaiian Sugar Refining Co.
  Banker's Warehouse.
  Fort Bragg Dock.
Port Costa
  Granger's Dock.
  McNear Warehouses.
  Southern Pacific Railroad ferry and other structures.
  Associated Oil Co.
Benicia
  U. S. Shipping Board pile boom.
  Southern Pacific Railroad ferry.
  Municipal wharf and ferry.
  Southern Pacific Railroad river boat docks.
  G. W. Hume & Co.
  Kullman-Salz Co.
  U. S. Arsenal piers.
Martinez
  Municipal wharf and ferry.
  Shell Co. of California.
  American-Oriental Oil Co.
  Mountain Copper Co.
  Electrolytic Zinc Co.
  General Chemical Co.
Avon
  Associated Oil Co.
Bay Point
  Pacific Coast Shipbuilding Co.
  Coos Bay Lumber Co.
Mallard
  San Francisco-Sacramento Railroad ferry.

Chipps
    San Francisco-Sacramento Railroad ferry.
Dutton
    San Francisco-Sacramento Railroad trestle and drawbridge.
Pittsburg
    Small docks.
Antioch
    Municipal dock.
    A. T. & S. F. R.R. dock.

Damage

The damage done by the marine borers in this northern area, and which has become evident only within the last two years, has been estimated by the Committee, in terms of replacement and repair, and on a basis of considerable detail, to be in excess of $15,000,000.

HYDROGRAPHIC PHASE

REPORT OF THE SUB-COMMITTEE ON THE HYDROGRAPHY OF SAN FRANCISCO BAY

The waters of the San Francisco Bay system are made up of three more or less distinct areas, as shown by the accompanying map, known as San Francisco Bay, San Pablo Bay, and Suisun Bay. The water surface of these bays is not delimitable with perfect accuracy, but it will suffice to say that, at ordinary high tide (not including tide marsh lands), it has an area of about 460 square miles. This area is made up of the main San Francisco Bay, 288 square miles; San Pablo Bay, 112 square miles (see University of California Publications, Vol. 14, No. 1, p. 20, Albatross Surveys); and Suisun Bay, about 60 square miles.

The Golden Gate, through which the San Francisco Bay is connected with the ocean, is the narrows between Fort Point on the south and Lime Point on the north. Oceanward from the Golden Gate is the outer bay. This is hemmed in on the north by the cliffs of the Marin shore which end their concave sweep at Point Bonita and on the south by the bluffs of the San Francisco shore which have their westerly termination at Point Lobos.

Through this outer bay and through the Golden Gate, which is less than a mile in width, there is a tremendous tidal flow which has cut and holds the gorge near its narrowest point to depths of more than 300 feet.

Some five miles beyond the Heads, as Point Lobos and Point Bonita are commonly called, lies the bar. Here is the crescent shaped crest of a great sand-bar, subject to change under the ever varying forces of nature and yet so little altered in the half century during which it has been repeatedly surveyed that no characteristic or predominating tendency to change has yet been discovered.

The watershed area tributary to Golden Gate is about 62,000 square miles. Of this area 2014 square miles are tributary to the main or south arm of the bay; 964 square miles are directly tributary to San Pablo Bay; 557 square miles are in the watersheds of small streams discharging into Suisun Bay; 58,000 square miles are embraced within the drainage basins of the Sacramento and San Joaquin Rivers, which discharge into the upper end of Suisun Bay; and 460 square miles, as above noted, are bay water surface.

The Sacramento and San Joaquin Rivers, the drainways of the Great Central Valley of California, meet at Collinsville at the head of Suisun Bay. This bay is of particular interest at this time because it is, at low stages of the rivers, the principal mixing pool of river and ocean waters. Its tidal area under natural conditions was increased by about 100 square miles of marsh lands (then submerged at high tide but now to a large extent reclaimed) lying principally along its northern shore. From Suisun Bay the waters of the rivers reach San Pablo Bay through the Carquinez Strait.

In seasons of substantially normal weather conditions the water of Suisun Bay, which is brackish in the fall, is gradually freshened by the increased stream flow which begins in September or October. The discharge of the rivers into the bay increases at this time from various causes. There is a decrease in the evaporation from the water surface of the rivers and delta channels and a decrease in the irrigation draft, and the winter rains begin about this time of year. This year (1920) the waters of Suisun Bay had reached their maximum salinity about the middle of September and, a few weeks later, particularly after the winter rains commenced, the increasing flow of the rivers accelerated the freshening of the water in the upper end of Suisun Bay so that by the middle of November the brackish water had there been displaced. The seasonal rainfall at the end of December (July 1st to December 31st, 1920), has been about 40 per cent in excess of the normal. At the time of greatest salinity during 1920 the bay water at Collinsville just below the mouths of the two rivers, at high tide, slack water was about one half ocean water; and at low tide slack water somewhat less than one third ocean water.

Some evidence was presented within the last few months in the pending Antioch case, to the effect that about 1869 or 1870 under then prevailing conditions, before extensive reclamation works had been carried out, the presence of bay water was noticeable by brackish taste as far up stream as Three Mile Slough in the San Joaquin River. The presence of brackish water at Antioch, brought up from the bay by the flood tides, in the fall months, seems to have been frequently noted, and its presence in sufficient quantity at certain times, in past years before the question of the effect of the reduction of river flow by the irrigation draft was raised, is evidenced by the very general use of cisterns by the residents of Antioch. In these cisterns, some of which have been in use 30 years or more, water obtained from the river in the spring of the year, when the river at Antioch is fresh at all tides, is held for domestic use later in the season.

No discussion of salinity conditions in San Francisco Bay for any year or sequence of years would be complete without some reference to the amount of fresh water which is brought into the bay by tributary streams. Some idea of the relative amount of fresh water reaching the bay region can be obtained from the rainfall records if the fact is borne in mind that run-off is not proportional to rain but that in wet years, that is in years of much rain, the portion thereof which reaches the streams is larger than in dry years or years of light rainfall. (The climatic years and not the calendar years are here referred to.) A diagram is herewith submitted (Fig. 1) showing the rainfall in central California since 1849. The rainfall is noted in per cent of the normal annual rain. The beginning of the climatic or seasonal year was taken at July 1st.

The normal annual delivery of fresh water into San Francisco Bay by the two principal rivers which discharge into the bay is approximately 35,000,000 acre feet. About 85 per cent of this water reaches the bay in the first six months of the year, and rather less than 15 per cent thereof in the last six months. A second diagram (Fig. 1) shows the seasonal water output of Sacramento River based on a summation of the discharges of the Sacramento River at Red Bluff and its principal tributaries at foothill points, not including Stony, Cache and Putah creeks, or other lesser tributaries. For the years preceding the period covered by records of the U. S. Geological Survey, the discharge for the climatic year has been approximated from rainfall and it has thus been possible to give the eye a picture of the relative amount of water annually discharged into Sacramento Valley by these streams for the full period of 70 years covered by rainfall records.

What is presented in the diagram, although applying to only a part of the area tributary to the upper end of the bay, being expressed in per cent of normal flow, may, nevertheless, be accepted for the present as fairly well representing the relative annual fresh water accession of the bay from both the Sacramento and the San Joaquin Rivers, subject, however, to some correction for greater diversion for irrigation in recent years than formerly.

The normal low water output of the Sacramento and San Joaquin Rivers at the point where they discharge into Suisun Bay, as it was before disturbance by human activities, is not ascertainable with any

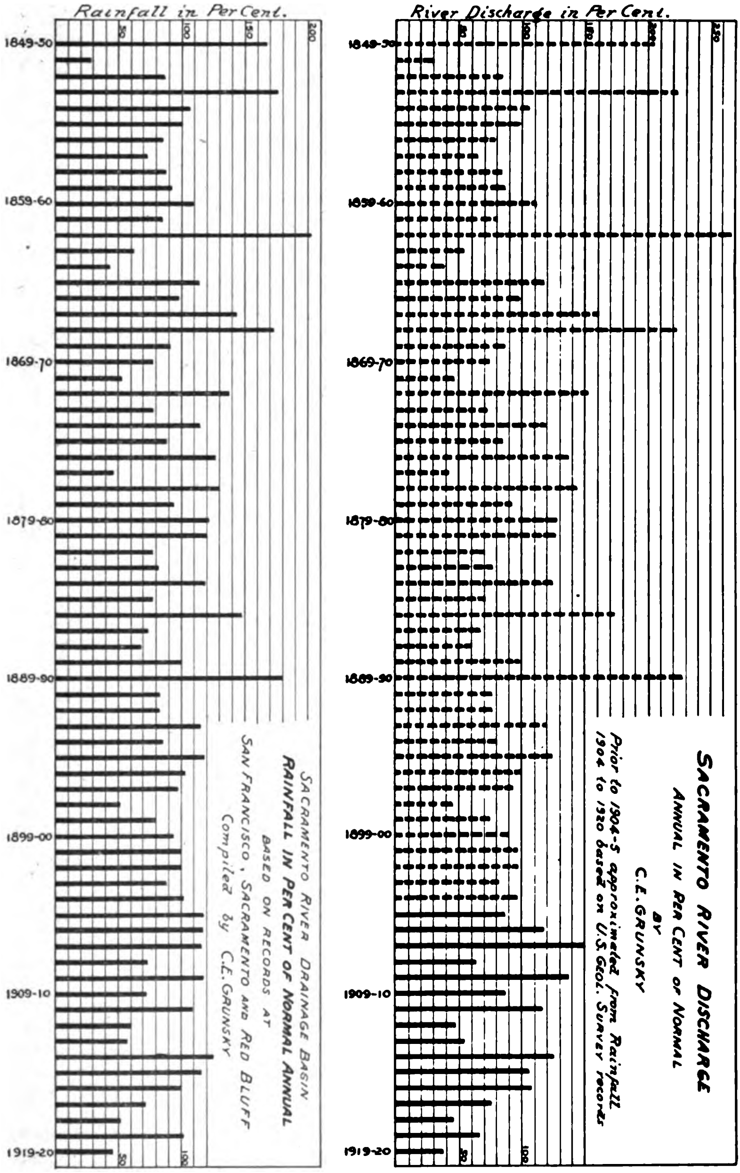
Rainfall in Per Cent.
50
100
150
200
1849-50
1859-60
1869-70
1879-80
1889-90
1899-00
1909-10
1919-20
SACRAMENTO RIVER DRAINAGE BASIN
RAINFALL IN PER CENT OF NORMAL ANNUAL
BASED ON RECORDS AT
SAN FRANCISCO, SACRAMENTO AND RED BLUFF
Compiled by C.E. GRUNSKY
River Discharge in Per Cent.
50
100
150
200
250
1849-50
1859-60
1869-70
1879-80
1889-90
1899-00
1909-10
1919-20
SACRAMENTO RIVER DISCHARGE
ANNUAL IN PER CENT OF NORMAL
BY
C.E. GRUNSKY
Prior to 1904-5 approximated from Rainfall
1904 to 1920 based on U.S. Geol. Survey records

Fig. 1

great degree of precision. There are no records of direct measurement. In the early history of the State, measurements of the stream flow were not made, and now the effect of human activities upon this flow is material.

To give some idea of the amount and range of the annual water delivery into Suisun Bay by the Sacramento River, which delivers about four times as much water as the San Joaquin, Table I has been prepared showing the flow of the river in selected recent years.

The figures presented in the table, being a summation of the discharges of Sacramento River at Red Bluff, of Feather River at Oroville, of Yuba River at Smartsville, of Bear River at Van Trent, and of American River at Fair Oaks, will give some idea of the normal discharge of Sacramento River and the range of its mean monthly discharge, all amounts noted being based on the estimates of the U. S. Geological Survey.

TABLE I

SACRAMENTO RIVER

Summation Discharge of Sacramento River at Red Bluff and of the River's Principal Tributaries.

	Normal	Seasons of light rainfall				A flood year
Month	discharge sec.-ft. Rain 93%	1911–12 sec.-ft. Rain 59%	1912–13 sec.-ft. Rain 56%	1918–19 sec.-ft. Rain 101%	1919–20 sec.-ft. Rain 45%	1906–07 sec.-ft. Rain 116%
October	7,850	7,616	6,631	9,528	6,934	8,188
November	10,600	8,195	15,937	9,910	6,515	9,751
December	17,300	7,914	11,585	10,006	10,024	31,480
January	45,744	17,870	24,990	18,009	7,930	39,070
February	51,751	14,721	16,368	53,560	8,138	98,610
March	53,794	23,026	18,853	38,650	19,270	139,050
April	51,975	21,102	39,126	47,940	29,820	91,700
May	43,908	37,027	36,319	36,186	24,218	60,254
June	26,800	21,261	15,742	10,850	10,984	45,532
July	11,679	8,188	8,339	6,908	6,371	22,205
August	7,605	6,319	6,642	6,201	5,365	11,186
September	7,194	7,530	5,872	6,182	5,035	9,086
Yearly mean	28,000	15,070	17,190	20,960	11,720	47,260

NOTE.—The normal discharge of Sacramento River noted in Table I is the average of the monthly estimates by the U. S. Geological Survey for the period 1905 to September 30, 1920. It is probably somewhat below the actual normal because there has been a preponderance in recent years of seasons with less than normal rain. The rain noted in the table is expressed in per cent of normal and is based on the records of rainfall at San Francisco, Sacramento and Red Bluff. The figures are used only to give an approximate indication of the amount of rain in the watershed of Sacramento River which produced the runoff.

Not only should the facts relating to the variation in the seasonal delivery of water by the rivers into the bay be given consideration when the degree of salinity in different years is compared, but it is likewise important to bear in mind that the mean monthly discharge of the rivers from the mountains into the valley varies within wide limits. The natural normal combined flow of the two rivers for the several months shows a range from a minimum monthly mean of about 7000 second-feet to a maximum of about 70,000 second feet, while in certain individual years the range has been much greater, as for example in the season 1906–7 (see Table I). The curves shown in Fig. 2 will give a fair idea of the river stages throughout the year in per cent of the normal mean annual discharge. The information is given in this diagram for Sacramento River and for both rivers combined.

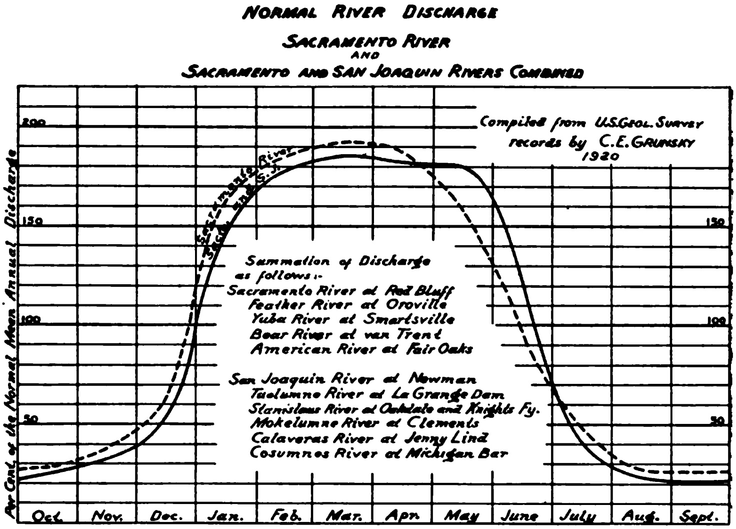

Fig. 2

Under natural conditions at flood stages the greatest momentary discharge of both rivers combined probably quite frequently reached 200,000 to 300,000 second feet. The Government project for flood control will withdraw from inundation the natural flood basins which flanked the rivers, or will materially reduce their areas. The retarding effect of these basins upon the flood volume will be eliminated or greatly reduced and the peak of the flood discharge will be raised. Sacramento River alone may, after this project is carried out, be expected to then deliver under conditions such as prevailed at the flood of March, 1907, some 500,000 to 600,000 second feet at its extreme stages.

It is interesting to note in this connection that the volumetric contents of Suisun Bay are about 480,000 acre feet at low tide and about 700,000 acre feet at high tide, and that the volumetric contents of San Pablo Bay are about 1,000,000 acre feet at low tide and nearly 1,500,000 acre feet at high tide. These volumes of water are pushed back and forth by the tides, becoming more salty during the protracted annual low water stage of the rivers and freshening again to a greater or less degree as the rivers rise to their winter and spring high stages.

It is of considerable importance in the study of the habits of the Sacramento and San Joaquin Rivers, that the characteristics which are most marked today were faithfully described more than a century ago. From the Publications of the Academy of Pacific Coast History the following is quoted. Fray Narcissus Duran in his diary writes:

> "May 16, 1817. All along the Sacramento River it is like a park, because of the verdure and luxuriance of its groves of trees. Still, it is difficult to land, because everything is inundated, due to the rise of the river from the melting of snow."
>
> "May 19, 1817. (Continuing up the river near the site of Sacramento.) The river is much swollen and is flooded on both sides, so that one can scarcely alight upon land."
>
> "May 24, 1817. At midday we set out to join the commandant at the strait of Chupcanes (Carquinez), which we reached at six o'clock in the afternoon, finding the said gentleman there; he had arrived in the morning. We traveled this afternoon as far as the mouth of the San Joaquin. It is necessary to pass this at high tide, because there is a sand bar, and the launches are blocked by it. There is this difference between the Sacramento and the San Joaquin; the latter carries less volume of water, although in some places it is wider; and in all that part which we have traveled there is nothing but tule, without a tree under which the navigator may find shade, nor a stick of firewood with which to warm himself; whereas the Sacramento, when it is not flooded, has dry land on both banks covered with poplar groves, as has been said, and it seems to carry a greater abundance of water."

Commander Cadwalader Ringgold, U. S. Navy, reported his observations and surveys of 1849 and 1850. On page 39 of his report, the following important fact is announced:

> "At the lowest stages of the water the maximum depth available for vessels proceeding up the Sacramento River, owing to the obstructions existing in portions of the channels, does not exceed ten feet; from six to eight in the San Joaquin River."

The regimen of the two large rivers which discharge into the upper bays has been materially modified by human activities. Hydraulic mining contributed enormous amounts of sand and sediment to the natural sediment load of the two rivers—more particularly to that of the Sacramento River. It is not proposed to discuss this problem fully. It will suffice to call attention to the fact that under original conditions, tidal influence extended up Sacramento River as far as Sacramento. The tidal range was there in excess of 2 feet and extreme low water fell at times below the zero of the Sacramento gage. (The zero of the Sacramento gage is .48 of a foot below mean sea-level.) Under the effect of hydraulic mining the bottom of the river was raised by sand deposits and the rising bottom forced up the water surface of the river so that the lowest low waters of the years 1895–99 averaged about 8 feet higher than those which prevailed originally.

In recent years the bed of the Sacramento River has again been lowered to near its original position. The principal causes which have contributed to this depression of the river bed are the cessation of hydraulic mining on a large scale; the restraining of mining debris under Government direction at or near the mines; the extensive dredging operations carried on in the rivers to secure material for river levees, and to enlarge the lower reaches of the river, and the scouring action of the river, which is better confined between the river levees in recent years than theretofore.

The changes which have occurred in the low water elevation at Sacramento are well illustrated by the following figures from gage readings at Sacramento:

TABLE II

LOW WATER AT SACRAMENTO

Gage Readings at Lowest Stage of Tide

Period	Average of annual lowest gage readings	Period	Average of annual lowest gage readings
1849–53	0.3	1889–93	7.7
1854–58	1.0	1894–98	7.9
1859–61	1.6	1899–03	7.2
1862–73	no record	1904–08	6.8
1874–78	5.3	1909–13	4.4
1879–83	6.7	1914–18	3.2
1884–88	7.3	1919–20	0.4

As the destructive work of the teredo in the upper bay region apparently did not become serious until within the last two or three years, it is of particular interest to note the fact that the climatic year 1917–18 was a year of very light rainfall and small run-off (see Fig. 1); that the rainfall of 1918–19 in aggregate amount was about normal at San Francisco and Sacramento but that it was so distributed in time that it produced materially less than normal runoff from the watersheds of the Sacramento and San Joaquin Rivers, and that both rainfall and runoff for 1919–20 were less than 50 per cent of normal.

During the low water period of these recent years the irrigation draft upon the Sacramento and San Joaquin Rivers was increasingly heavy, largely due to rice growing in the Sacramento Valley, and there was a period of several months of the year 1920 during which it seems to have been a fact that more water was used for irrigation on the delta lands of these rivers than was supplied to the delta channels by the two rivers. In such circumstances some of the bay water which entered the mouths of the rivers on each flood tide was retained in the river channels and caused bay water, under the influence of tidal action, to get up stream at high tide to points in the Sacramento River somewhat above Isleton and in the San Joaquin River to points probably above the mouth of Middle River. The salinity records of the State Water Commission show a chlorine content on the San Joaquin River at Blake's Landing (Venice Island) in September, 1920, of 56 parts in 100,000 at high tide and 40 parts at low tide, representing about 92 parts and 66 parts of common salt respectively. While a portion of this salt is probably attributable to the presence of some bay water, care is necessary in interpreting this information in view of the following from the report of W. E. Allen on "A quantitative and statistical study of the plankton of the San Joaquin River and its tributaries in and near Stockton, California, in 1913," in which he says on page 21: "In spite of the low water it is not at all probable that sea water ever had any influence here except in causing tides." He then notes the salinity of the river water at a point in the river from 400 to 800 yards up stream from the mouth of Stockton channel at about 30 day intervals throughout the year. The highest salinity was shown by the samples taken on November 22nd. The chlorine content of the water was then 66 parts in 100,000. This is equivalent to about 99 parts of common salt in 100,000 parts of water. The situation relating to the up-river penetration of bay water is aggravated, too, by the fact that the work of channel enlargement in progress since 1913 and being done by the U. S. Government, in coöperation with the State of California, on the Sacramento River below Rio Vista has been a material factor in facilitating tidal flow in the lower reaches of that river and in augmenting the circulation of water around Sherman Island, thereby expediting the up-river advance of the bay water.

The following data relating to the salinity of the upper bay and river waters are derived from public records being collected and compiled by the State Water Commission.

TABLE III

RANGE OF SALINITY IN THE LOWER REACHES OF SACRAMENTO AND SAN JOAQUIN RIVERS AND IN THE HEAD OF SUISUN BAY IN 1920

Based on samples taken for the California State Water Commission at high and low tides. Salinity is given in parts of salt per 100,000 parts of water. (Reduced from chlorine contents by Knudsen's formula.)

Station	Tide	June*	July*	August	September	October	Nov.
Rio Vista....	Low	....	22 to 35	49 to 240	50 to 160	18 to 26	....
	High			49 to 380	105 to 430	29 to 137	....
Collinsville	Low	5 to 20	18 to 525	650 to 1220	875 to 1345	35 to 560	9 to 85
	High			825 to 1445	1210 to 1560	208 to 1058	9 to 260
O. A. & E. R. R. Fy. Suisun Bay	Low	10 to 130	55 to 930	1045 to 1285	1310 to 1700	335 to 1300	9 to 312
	High			1060 to 1590	1670 to 1800	613 to 1470	9 to 619
Antioch.......	Low	....	17 to 640	275 to 865	780 to 975	70 to 589	29 to 109
	High			665 to 1350	1040 to 1390	123 to 1058	29 to 114

*NOTE: No information is available as to the stage of the tide at which the samples of water for salinity tests were taken preceding July 20th.

Concerning the tides in San Francisco Bay the late Prof. Geo. Davidson, in the "Pacific Coast Pilot," says:

> "From the lower low water (low water large) the tide rises for about 7¼ hours, say 4.4 feet, to the smaller of the two high tides (high water small); then falls 1.4 feet in less than 4½ hours to the 'low water small' which is higher than the preceding low water; then rises, say 2.9 feet in 6¼ hours to the higher high water or 'high water large'; it then falls again 5.8 feet in over 7 hours to the lower low water, or 'low water large.' "
>
> "Instead of the above figures, the fall from high water small or 'half tide,' to the 'low water small,' may range from 3½ feet at one position of the moon to 0.3 feet at another; in the latter case there will be apparently a long stand of about 5 hours. . . . .
>
> "The average difference of the higher high and lower low waters of the same day is 5.2 feet, with a greatest observed range noted for February 8, 1876, of 9.93 feet."

It may be noted in this connection that the predictions as published by the U. S. Coast and Geodetic Survey in the Tide Tables for 1920 at Yerba Buena Light show:

Expected mean range of tides, 4.2 feet.
Expected mean range of spring tides, 6.0 feet.
Expected maximum range in 24 hours, 8.7 feet.

Careful studies were made by the late Dr. G. K. Gilbert of the tidal movements in San Francisco, San Pablo and Suisun Bays,* as the result of which the following may be noted:

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* See Professional Paper No. 105, U. S. Geological Survey, "Hydraulic Mining Debris in the Sierra Nevada," by Grove Karl Gilbert.

The average volumes of great tropic ebb currents, as dependent on the effective tidal prisms of bays, other bodies of open water and marsh tracts are estimated by Dr. Gilbert as follows:

At Golden Gate, 91,948,000,000 cubic feet or 2,110,000 acre feet.
At San Pablo Narrows, 39,800,000,000 cubic feet or 910,000 acre feet.
At Carquinez Strait, 20,580,000,000 cubic feet or 470,000 acre feet.

He gives the following as the effective ranges of tide (great tropics):

In Golden Gate, 6.2 feet.
In San Pablo Bay, 6.2 feet.
In Carquinez Strait, 7.2 feet.
In Suisun Bay, 7.3 feet.

For a tidal range of 6 feet at the upper end of Suisun Bay when the rivers are at their low stages, that is generally from some time in July to November, the volume of water which is required to fill the tidal prism in the lower reaches of the Sacramento and San Joaquin Rivers may be noted approximately at 57,000 acre feet for the San Joaquin River and 25,000 acre feet for the Sacramento River.

The discharge of the rivers, when material, during the time interval between the extremes of tide must, however, be given consideration if a comparison is to be made between the volume of flood flow from the bay which is required to fill this tidal prism and the volume of water delivered into the bay from the rivers on the ebb flow. The river discharge decreases the volume of water moving up stream on the flood tide and increases the volume of water moving down stream on the ebb tide.

It appears from the foregoing that there are a number of factors to be considered in any discussion of the salinity of the upper bay and lower river waters, particularly when conditions in any year are to be compared with those in another, and, too, when any forecast is attempted as to future conditions.

Principal among these factors are the following:

1. The seasonal water output of the Sacramento and San Joaquin Rivers, and the occurrence in sequence of years with normal runoff conditions.

2. The distribution of the seasonal water output to the several months of the year.

3. The effect of human activities upon the river discharge, referring particularly to:

a. The acceleration of the flood discharge resulting from the reclamation of large areas which, under natural conditions, were subject to inundation. The natural flood basins acted as retarding basins, prolonging the river's flood stages, thereby impeding and delaying the arrival of ocean water in the upper bays. The flood basin has already been materially reduced.

b. The reduction of the discharge of the rivers into Suisun Bay, notably at their low water stages, by the withdrawal of water for irrigation in the deltas of the rivers and at up-river points.

c. The regulating effect of storage reservoirs tending to augment the low water discharge of the rivers.

d. The accession of return water which, though relatively small in amount, is, nevertheless, increasing as irrigated areas are being extended. This not only affects the stream flow but also the quality of the water. The return water contains more mineral matter in solution than the natural river water.

e. The modification of channel alignments and dimensions, resulting from work done in building levees and particularly from the work being done by the United States under coöperation with the State in the lower reaches of Sacramento River, which have a material effect upon the tidal flow in the lower reaches of the rivers.

C. E. GRUNSKY,
Chairman.

Sub-Committee:
C. E. GRUNSKY,
C. S. JARVIS,
Capt., 4th Engineers, U.S.A.

BIOLOGICAL PHASE

THE MARINE BORERS OF THE SAN FRANCISCO BAY REGION

By CHARLES A. KOFOID

The cosmopolitan character of the distribution of the marine borers depends upon the ease with which their larval stages may be carried by currents of the sea, or in the water tanks of steamers, and upon the facility with which the borers themselves may travel long distances in driftwood, in exposed wood of vessels or in timber rafted by sea. This makes it a biological certainty that all great ports are subject to repeated invasions by borers from other localities and that as their shipping facilities increase and the movement of commerce accelerates, the area within their limits available for occupation by borers of both native and foreign origin will increase, and that the borers will invade the new territory, except as they are restricted by preventive measures.

The port of San Francisco has been no exception to this rule of the sea. The growth of its lumber trade, its increase in wharves and docks, and the rapid expansion of its commerce have been accompanied by the constant necessity of engineering precautions against the certain and often swift destruction of submerged unprotected marine structures of wood within its confines. The recent period of shortage in rainfall has greatly extended the area in which the borers are to be found.

The marine borers now at work in this locality comprise the most widely known and most destructive representatives of the groups to which they belong, with the addition of one other species of what seems to be as yet a purely Californian pest.

The marine borers belong to two groups of animals, to the Mollusca and to the Crustacea. The boring mollusks all belong to one family, the Teredinidae, a family of the Lamellibranchiata, a class of the Mollusca, which includes the oysters, cockles, razor shells and clams, all bivalves, some of which, as the clams and razor shells, find shelter by burrowing in the sand and mud and pushing up their siphons to the surface of the mud and circulating the water through their mantle cavities, thus obtaining their oxygen and food supply.

This burrowing habit and the mechanism for accomplishing it reaches a high degree of specialization in two families of Lamellibranchs, the Pholadidae, which burrow while small into the mud, shale, or harder rock, and as they increase in size, excavate a larger and larger cavity (pl. 11, fig. 1). These borers remain clam-like in form and appearance with short bodies, stout large shells, roughened on the outer surfaces for drilling purposes. Only one species of this family is found sparingly in wooden structures in San Francisco Bay, where it often occupies the abandoned burrows of other borers. Rock boring species of *Pholas* are sometimes found in timbers and a tropical West Indian species, *Martesia striata,* is found elsewhere in timbers of wooden ships coming from that region. Another genus and species of pholad mollusks, *Xylophaga dorsalis,* lives in fixed and floating timbers on European coasts in which it makes shallow burrows one and a half inches in depth. It resembles *Teredo* in the shape of its shells but has no pallets, and does not line its tube with shell. It does serious damage to marine structures and to submarine cables by boring into the insulation.

The rock-boring mollusk, *Pholadidea gabbi,* which lives in the rock bed and submerged boulders of the Golden Gate (pl. 11, fig. 1) is occasionally found in wooden piling in San Francisco Bay. One specimen was found in a pile from Tiburon and the University has a specimen of large size from a pile at Sausalito. It has not, as yet, been found in concrete piling or other marine concrete structures.

The family Teredinidae on the other hand, is composed entirely of burrowing species most of which drill slender tubes into wood by means of their shells and have a pair of plumose or paddle-shaped pallets near their siphons which serve as plugs to close the outer end of the burrows against intruders. These borers line their burrows with a film of pearly nacre and drill tubes of different lengths up to and even exceeding four feet in length, into submerged or floating wood. They seem to have the boring instinct well-developed and continue drilling throughout most of their life. Each different species has a characteristic general size of body and shell and character of tube, but the diagnostic features of chief utility in determining the different genera and species are the pallets. The shells change constantly with age and wear, and the burrows are greatly modified by local conditions. The pallets also are subject to considerable change with age and locality but nevertheless still afford the most easily examined and most reliable criterion for the determination of the species.

This family of borers is represented in San Francisco Bay by at least three different species belonging to the two representative genera of the family. These are the well-known and notorious *Teredo navalis* Linn., or pileworm of cosmopolitan distribution, *Teredo diegensis* Bartsch, a small species of the California coast, and *Xylotrya setacea* Tryon, the large borer of the Pacific Coast. We will now consider these species in greater detail.

Xylotrya setacea Tryon

The Giant or Plumed Pileworm

Plates 12 to 18

This is the largest of the three borers found in the bay. When full grown in our waters it measures as long as two feet in length and has a diameter at the head or shell-bearing end of three-fourths of an inch. Tubes over three feet in length and seven-eighths of an inch in diameter have been found in old piling on the San Francisco waterfront.

The body (pl. 16) lies in the burrow, which enters the pile horizontally and generally turns downward at once and expands within one or two inches to a nearly uniform diameter throughout the rest of its course. The head, anterior, or shell-bearing end (pl. 18, fig. 1) is at the bottom of the burrow with the shell resting against the end or withdrawn or even partitioned off from the end of the burrow by a shelly membrane in old specimens. The mouth of the burrow is a minute pore from which the mollusk protrudes its two siphons, and which it closes by means of the two long plumose pallets (pl. 17, fig. 1) attached behind the siphons. This is the posterior end of the body and the end at which water for respiration and food enter and from which the chips from the drilling of the wood and the excreta are removed. The body is opaque whitish, and less translucent than that of species of *Teredo*. It is of nearly uniform caliber throughout and the shell is considerably wider than the adjacent neck region. The posterior or siphon-bearing end of the body bears three structures which are very characteristically developed in the genus *Xylotrya*. They are the pallets, the siphons, and the collar.

The pallets (pl. 28, fig. 1) are attached on the right and left sides of the body and their stalks extend beneath the collar. They project posteriorly as two curved, stout, feather-shaped structures one to two inches in length, and nearly one fourth of an inch in width. The stalk enters the side of the body where it is attached to the retractor muscle. The body of the pallet is composed of a row of repeated parts fifteen to thirty in number, tapering distally, each representing the single pallet of *Teredo*. These are convex outwardly, concave on their inner faces and enclose within the cavity thus formed the two siphons. Each segment is recessed posteriorly and its sides are prolonged in horny filaments while the calcareous body is continued anteriorly as a shaft which fits into the cup-shaped cavity on the inner face of the next anterior segment. The segments fit together like a series of flattened funnels. The posterior tips of the two pallets when their median faces are apposed form a slightly tapering cone which fits the outer end of the burrow and encloses in its center the delicate siphons. It thus forms a hard resistant plug which can be inserted at the inlet to keep out intruders and yet leave enough room for the water to percolate in around the segments of the pallets for purposes of respiration and feeding, while the bristling points of the segments make an effective barrier against any small marauder which might attempt to force his way into the orifice and burrow. When forced into the outlet they effectively close it. In old specimens it appears that the outermost segments may be dropped off from time to time.

The siphons (pl. 17, fig. 1) form the bifurcated posterior end of the body projecting beyond the collar. The longer siphon is the ventral and incurrent one, the shorter the dorsal or excurrent one. The siphons of *Xylotrya setacea* are less pigmented than those of *Teredo navalis* and are relatively stouter, less deeply cleft and more nearly equal. The pigment forms two narrow bands of small bright reddish granules in the median line facing each other on the walls of the siphons.

The collar (pl. 17, fig. 1) is a muscular fold of the mantle enclosing the base of the pallets. This serves as a zone of adhesion of the outer or posterior end of the body to the wall of the burrow and thus facilitates the retraction of the body, its movements in the burrow and the retraction and protrusion of the posterior end with its siphons and pallets.

A side view of the structure of the body will show the arrangement of the viscera and will illustrate the relation of the parts to the activities of the animal.

The body of *Xylotrya* forms a cylindrical sack with the mouth at the inner, shell-bearing, or anterior end, and the two siphons at the tapering posterior end. The other surface is formed by the mantle, which in oysters and clams is not closed along the length of the ventral side of the body as in the borers. This makes a long tube of the mantle cavity which is separated into a dorsal or anal excurrent canal and a ventral incurrent one. The mantle secretes the shell, the pallets, and the pearly lining of the burrow. Its reflected surface on the anterior margins of the shell provides for the continual growth of this boring organ and at the posterior margin of the shell the mantle is greatly thickened in a ring which forms a sort of a washer which keeps the chips of wood from getting between the mantle and the wall of the burrow.

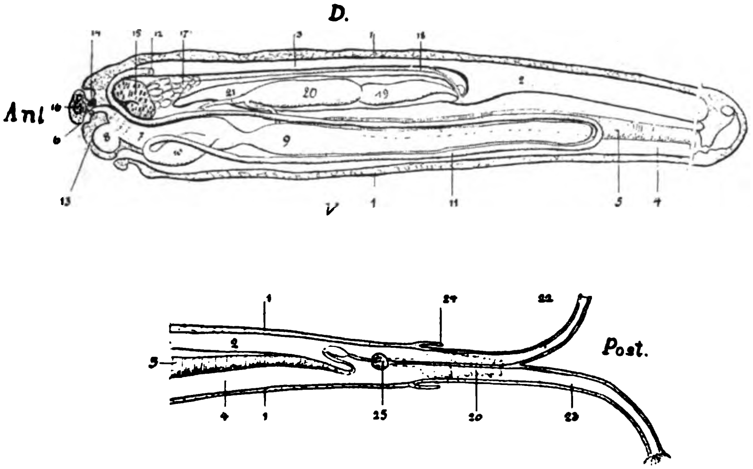

Fig. A. Diagrammatic longitudinal section through the body of *Xylotrya* (after Moll [1914, fig. 6]). Enlarged about 3 diameters. Abbreviations. *Ant.*, anterior end; *Post.*, posterior end; *D.*, dorsal side; *V*, ventral side. A cross-section of the right half of the body is shown at the right of the upper figure. 1, Mantle; 2, dorsal cavity leading to anal or dorsal discharging siphon; 3, anal canal; 4, ventral or mantle cavity leading from ventral or intake siphon; 5, gills; 6, mouth; 7, oesophagus; 8, sheath of the crystalline style; 9, caecum; 10, beginning of the intestine; 11, intestine; 12, rectum; 13, foot; 14, ligament of the shell; 15, posterior adductor muscle; 16, anterior adductor muscle; 17, kidney; 18, ureter; 19, auricle of the heart; 20, ventricle; 21, posterior aorta; 22, anal or dorsal siphon; 23, ventral or incurrent siphon; 24, mantle fold or collar; 25, muscle of the pallet; 26, pallet.

The opening at the anterior end of the body is surrounded by the two shells over whose margin the edge of the mantle may be reflected for the secretion of additions to the shell. In the center of this opening is the muscular sucker-like foot which serves to anchor the head end to the end of the burrow and at the same time to allow a considerable freedom of the opening and closing movement of the valves of the shell about the foot as an axis for boring. The foot can be moved about and the course and direction of the burrow changed.

Dorsal to the foot in the groove about it is the mouth with two ciliated flaps whose function it is to guide the food particles into the mouth (fig. A, 6).

From the mouth the food, and, during the periods of boring, the chips of wood, pass into the oesophagus (17) opening into the stomach (10), thence through the looped intestine (11) to the dorsally placed anal opening (12). Attached to the stomach is a capacious pouch which serves as a receptacle for the wooden particles rasped off of the wall of the burrow by the shell. It appears from an examination of the intestinal contents that a considerable part, if not all, of the wood rasped off by the shell passes through the digestive tract. The caecum appears to serve as a reservoir for the temporary storage of the particles during rapid excavation. The functions of plankton feeding and of wood boring may be intermittent, the caecum serving for storage of the wood while feeding and digestion is in progress. Wood particles exclusively appear to be found in the caecum while plankton and wood fill the intestine. The wood does not appear to be digested.

Greatest interest attaches to the shell (pl. 18, figs. 1, 2) as the tool of excavation and the mechanism of its operation has long puzzled biologists. The shell is a bivalve one but the two valves are not attached to each other by a continuous dorsal hinge as in the clam, but are widely separated except at two knob-like projections meeting in the middle line which serve as fulcra for the rocking movement of the two shells. In side view (pl. 18, fig. 2) the shells are seen to have a deep right-angled notch on the anterior or growing border, while the posterior border is carried out in a long lobe. This posterior lobe is a long lever to the inner face of which the large posterior adductor is attached while the anterior adductor is attached in the projecting anterior lobe above the anterior notch. The rocking movement used in boring is brought about by these two muscles common to all lamellibranch mollusks, the anterior and posterior adductor muscles. These muscles in *Xylotrya* are apposed to each other in such a way that the contraction of the small anterior adductor pulls the anterior edges of the shell towards each other around the circular foot, while the contraction of the posterior one spreads these edges apart.

The longer lever of the posterior lobe, and the stouter reddish posterior muscle indicate that the outward thrust of the spreading shells is the one that does the rasping away of the wood, while the return of the shells to initial position ready for the next thrust is accomplished by the small weak anterior adductor on the shorter lever. The two shells thus rock in and out on the dorsal and ventral knobs as fulcra, with the two angles, anterior and posterior, as the ends of the levers operated respectively by the anterior and posterior adductor muscles. Their alternating contractions produce the rocking, but the cutting action is due to contact of the anterior face of the shell with the surface of the wood and the scraping of this edge over the wood by the outward thrust of the shell as the powerful posterior adductor muscle contracts. The shell is held in contact with the bottom of the burrow by the sucker action of the foot.

The cutting edge and surface is formed by a series of fine parallel ridges which extends posteriorly from the anterior margin parallel to the angled margin. These ridges are about 0.04 mm. apart and each consists of an abrupt elevation, chisel-shaped in section with a sharp toothed margin. The heaviest service comes upon those ridges nearest the margin. As they are worn down by action, a new ridge is formed by the mantle in front of the youngest ridge. A new edge to the bit is thus constantly added as the old is worn down and the shell thus increases in size by constant addition on its margins. It is also strengthened by the addition of new layers of nacre on its inner face by the secretions of the mantle whose margin also secretes the cutting ridges. It is evident that during the secretion of a new cutting ridge the boring action must be temporarily suspended.

We have in the shell of *Xylotrya* and *Teredo* a cutting mechanism of exquisite delicacy of structure and operation, kept in repair for effective action during the active period of the borer's life. In heavily perforated wood and at the close of the season the mollusks often withdraw the shell from the end of the burrow and close off the end of the burrow by a partition of nacre. The chips cut away by this tool are minute strips of wood not over 0.01 of a millimeter in width and several times as long as wide. Their length may represent the interval between successive ridges of the shell.

The disposal of the sawdust thus created seems to be accomplished solely by passage through the digestive tract of the borer, though not for purposes of digestion, for it seems to pass unchanged through the tract. The total amount excavated by the borer exceeds considerably the volume of the body of the borer. The rate of excavation was found by Sigerfoos (1908) to be in the case of young *Xylotrya* 100 mm. in the first 36 days of burrowing or nearly 3 mm. per day. When the borers are active in the piling it is possible to hear the rasping of their tools on the wood by placing the ear against the exposed top of the pile.

Life History

Little is known of the life history of *Xylotrya setacea* beyond the fact that it does not seem to be breeding in San Francisco Bay in the autumn months. Sigerfoos worked out the life history of the Atlantic Coast species, *X. gouldi* Jeffreys. This species is stated by him to be hermaphroditic in young stages, while in the older ones the sexes are separate. The young become sexually mature about one month after they enter the wood while they are only about two inches long.

Xylotrya differs from *Teredo navalis* in extruding the eggs or sperm both freely into the sea water through the dorsal siphon. The breeding period at Beaufort, N. C., extends from May throughout the summer and was in full blast late in August, when observations ceased. The sperm cell meets the egg by chance in the water and the two unite. The egg then developes quickly, within three hours, into a free-swimming larval stage (pl. 26, fig. 2). The egg and larva are only about 1/500 of an inch in diameter. The larva forms a circlet of cilia or velum used as an organ of locomotion, and for the capture of food. It soon adds a pair of typical clam shells and a tongue-like, protrusible foot. After living a free life for about one month and increasing somewhat in size, the larva, because of the increased weight of the shells, tends to settle down, preferably upon wood and more often near the mud-line. It fastens itself to the surface of the wood by a sticky thread secreted by the foot which is thrown out as a lasso (pl. 26, fig. 2) to anchor the delicate animal in its precarious position on the pile where creeping crustaceans, snails, and worms are skirmishing about for food. It then retracts and eats its own velum, and transforms its tongue-like foot into a sucker, and by rapid growth changes the clam shells into shells of the borer type, grows out its elongating siphons and starts drilling operations. When first attached it is 0.75 mm. in length.

The following table gives the rate of growth of *Xylotrya gouldi* as determined by Sigerfoos (1908) at Beaufort, N. C., in midsummer.

	Length in millimeters
Just attached to the wood	0.25
12 days after attachment	3.00
16 days after attachment	6.00
20 days after attachment	11.00
30 days after attachment	63.00
36 days after attachment	100.00

At the age of 30 days it begins breeding and probably attains the adult size of two feet in length by the following summer.

The number of eggs produced is not known, but in *Teredo dilatata*, a large species attaining a length of four feet and a diameter of one inch, Sigerfoos (1908) estimated the number of ova at 100,000,000. This enormous number provides for the great wastage caused by the high death rate of the very susceptible stage in the first few hours of life of the new individual and for the great destruction of larvae in the plankton by plankton-feeding animals.

Burrows

The burrows of *Xylotrya setacea* differ from those of the two species of *Teredo* found in San Francisco Bay in two important particulars. They are larger and they present continuous minor deviations from the straight or curved course which *Teredo* pursues (compare plates 12 and 19, figure 2). Their burrows are therefore less symmetrical and regular than those of *Teredo.* These slight ridges which occur on the walls of the burrow of *Xylotrya* are due to abrupt but slight changes in direction of boring resulting from a shift in position of the foot and shell. They sometimes are less than millimeter apart. *Xylotrya* also sometimes withdraws from the end of its burrow and changes the course of its tube very abruptly, it may be at right angles at some distance above the end of the tube. This gives a false appearance of the crossing of burrows.

The burrow of *Xylotrya* enters the pile at right angles to the surface as a small pin hole and turns obliquely, usually downwards, enlarging rapidly within 2 inches of the surface to one-quarter inch and within four inches to three-eighths to one-half inch. It does not restrict its course to sap wood and in cases of sparse seeding of the borers, often bores obliquely deep into the wood before turning to run with the grain of the timber. For this reason, surface samples may not reveal lightly infected piling.

The largest burrows we have found in San Francisco Bay were seven-eighths inch in diameter in their lower portion and had a length exceeding 30 inches. At mud-line levels of the pile on the San Francisco and Oakland waterfronts (pl. 13, figs. 1, 2) they riddle the pile completely by transverse and oblique burrows because of the crowding of the borers and the consequent impossibility of boring with the grain. In comparison with *Teredo* in San Francisco Bay they are more sparsely set in the piling (pl. 25) and tend to bore more deeply into it. When *Teredo* is sparsely set it tends to run its burrows with the grain near the surface.

Xylotrya is generally found in association with *Limnoria* in our waters and the two invade the pile together although it is probable that when once *Limnoria* gets possession of the surface, *Xylotrya* has a small chance to get into wood. However, creosote-treated piling hollowed out by *Limnoria* sometimes has a few *Xylotrya* at work within the creosoted shell but not traversing it.

Distribution

The distribution of this species is imperfectly known beyond the fact that it occurs on California coasts. The genus *Xylotrya* is found in fossil wood of the Miocene at Astoria. It has long been known in San Francisco Bay, Oakland Estuary, Lake Merritt, the Golden Gate, Santa Cruz and San Pedro. It probably has a wider range of distribution both to the north and to the south.

The present investigation has revealed its presence on the San Francisco waterfront, from South San Francisco to Fort Mason, Tiburon, in old worn or in unprotected piling in the various moles on the Oakland waterfront, in the Oakland Estuary and San Leandro Bay, and in unprotected timbers in the Dumbarton Cut-Off. The most upstream location thus far detected is at Crockett, where a few large individuals were found by Engineer A. A. Brown of the California and Hawaiian Sugar Refining Company in piling heavily infected by *Teredo.* There is no evidence that it entered the upper bay beyond Carquinez Straits in any considerable numbers as did *Teredo.* It does not appear to adapt itself readily to the more brackish water as does *T. navalis.*

There is one record of unusual interest but some uncertainty. Among the piles pulled in 1920 at the Santa Fe Wharf at Antioch was one having a few *Xylotrya* burrows. This was an old pile driven twenty-nine years before. There was no evidence that this particular pile had seen service elsewhere and been infected in a prior location. Its exterior showed the same conditions as the other piling from the Antioch wharf. The number of tubes was very small and they were evidently very old. It is possible that they represent an infection of some earlier period of low water and upstream invasion of *Xylotrya.* Absence of authentic records regarding the piling makes a final decision on this case impracticable.

Destruction of Timber

The rate of growth of *Xylotrya* under existing conditions in the bay is seen in the fact that piles in the dolphin off the Alameda Mole driven in February, 1919, were so weakened at the mud-line, mainly by *Xylotrya,* that they had to be removed in November, 1920, that is in about twenty months. The effective destructive agent here was *Xylotrya. Limnoria* had eroded the surface for several inches and a light infection of *T. navalis* was also present, but its destructive effect was slight in comparison with that of *Xylotrya.* Piling in the neighborhood of the Golden Gate lasts only six months, owing to the combined action of *Xylotrya* and *Limnoria.* In so far then as our data go, it appears that the principal Molluscan borer to be guarded against in the main and lower parts of San Francisco Bay and on the ocean front where salinities are those normal to the sea or approach it is *Xylotrya setacea.*

In the heaviest cases of attack on piling by *Xylotrya* which have come to our attention the degree of destruction of the substance has been less than that in piling suffering from the severest attacks by *Teredo navalis.* This appears to be due to the relative numbers of borers settling on the piling. Under existing conditions, the seeding by *Xylotrya* is evidently less abundant and less close set than by *Teredo navalis* in its territory. On the other hand, the destruction by *Teredo navalis* in the main bay has as yet been rather lighter than that by *Xylotrya.* Two factors are at work to produce this result, the adaptation of *Teredo navalis* to slightly brackish waters, and of *Xylotrya setacea* to normal ocean waters, and the difference in breeding habits. *Teredo navalis* releases its larvae in the free swimming state and *Xylotrya* discharges its undeveloped sex cells into the sea. The death rate is naturally higher in the latter genus, and the settling of the larvae less abundant in consequence.

Teredo diegensis Bartsch*

Plate 19

This species was briefly described by Bartsch (1916) from San Diego and this name was also given by him in 1917 to the species found at Mare Island by Dr. A. L. Barrows in 1914–1916, but the latter is undoubtedly *Teredo navalis* and not *diegensis.*

Anatomical Structure

This is the smallest of the molluscan borers of this vicinity and the one of most restricted distribution in the bay. It does not appear that it took any part in the destruction of piling in the upper bay in recent years. For these reasons, it appears at present as though it was of least importance here from the industrial standpoint.

Teredo diegensis (pl. 19, fig. 4) is a small species, one to four inches, with a short body lacking the long extension from the visceral mass to the collar and pallets. It is therefore a stouter species, especially when the brood sac is distended with larvae. The body is also distinguished by the stout enlarged collar, and the dorsal bilaterally divided brood sac which distends the middle third of the body. Through its thin translucent walls the slightly brownish bivalve shells of the larval stages can be seen. The collar is exceptionally large in this species and is firmly adherent to the shelly lining of the tube. Fragments of this lining appear on two of the animals photographed (pl. 19, fig. 4). This attachment makes it very difficult to remove the living animal from its tube.

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* Identification by Dr. W. H. Dall, Smithsonian Institution, Washington, D. C.

Life History

The life history of this species is unknown except for the fact that it was found in November in San Francisco Bay with brood sacs full of larvae. These larvae look like minute clams and on November 5, 1920, at South San Francisco had a length of .025 inch. In a specimen two inches long there were 490 larvae in the brood sac. This number is relatively small in comparison with the enormous numbers of ova produced in *Xylotrya* and in *Teredo navalis.* It was also breeding in a season of the year in which neither of these other borers were sexually active.

The pallets (pl. 19, figs. 1–3) of *Teredo diegensis* are very characteristic and are subject to striking changes during the life of the animal. In the younger and many of the older and larger individuals the pallets are dark brown or black in the outer two-thirds of their length. They are fork-shaped with two lateral acuminate prongs whose length may equal the width of the pallet. These prongs taper gradually to a sharp point. The pallet is hand- or paddle-shaped, convex outwardly, concave on the inner face, and contracted anteriorly with a semicircular outline into the stout cylindrical shape, nearly as long as the expanded part of the pallet, which is continued under the collar into the retractor muscle.

The black color of the paddle and tips of the pallet is due to the horny black outer coat or periostracum covering the pallet. In some older individuals we find this outer covering stripped off and a whitish oval paddle forms the blade of the pallets in such cases. It is possible in some cases to pull the periostracum off and thus reduce the pallets to the oval form.

It is to be noted in this connection that the pallets of *Teredo norvegica* have been described in the two conditions found by us in *T. diegensis.* This fact together with the habit of carrying the larvae in a brood sac indicate that *T. diegensis* is rather closely related to *T. norvegica* but differs from it in the shape and size of its siphons, and in its smaller size.

The siphons (pl. 19, fig. 1) of *T. diegensis* are short and stout, and of nearly equal diameter and length. In a contracted condition the anal siphon is only a trifle shorter than the ventral one. They are not pigmented as they are in *T. navalis.*

Burrows

The burrows of *T. diegensis* differ from those of *T. navalis* in not attaining so large a size, in showing more irregularities in direction, and (at least in some timbers) in showing more clearly the serrations on the wall due to the action of the shell. They are also apparently more heavily lined with nacre. They enter the wood through a small hole, curve obliquely across the grain, and sometimes turn rather abruptly to run with the grain. They expand rather quickly after entering the wood to a diameter of three-sixteenths to one-quarter inch and do not increase distally to any noticeable amount. The largest tube we have thus far found is about six inches long and five-sixteenths inch in diameter. An examination of the burrows shows one characteristic instance among crowded burrows near the margin, of a burrow with frequent changes of direction, as though the animal was endeavoring to change the course of the burrow to avoid its neighbors but was baffled at every turn. The serrations on the wood correspond rather closely to the fine ridges on the shell, in their dimensions.

We have not found any evidence of either a longitudinal division or of transverse ridges or of chambered partitions in the outer ends of the burrows of this species, such as have been described in *T. norvegica* and some other species.

Distribution

This species is known only from San Diego Bay and San Francisco Bay, but may be expected in intermediate regions. It was reported on Dr. Bartsch's identification by Barrows (1917) at Mare Island and vicinity in 1914–1917, but it seems probable that the species present in that locality at that time was the same as the one there now, namely, *T. navalis.*

We have found *T. diegensis* only in one restricted locality in all of our extensive examinations of infected piling in San Francisco Bay. This was in some untreated boards and timbers in the wharf of the Schaw-Batcher Shipbuilding Company at South San Francisco on November 5, 1920. Oft-repeated examinations of new and old piling and experimental plants in the Upper Bay and at Mare Island have failed thus far to reveal a single specimen of *T. diegensis* in this locality, or in fact at any other place than the Schaw-Batcher wharf. Since we were unable to examine untreated pulled piling at that locality, we are unable to define the extent of its ravages. It is not as yet known to what extent it is responsible for destruction of piling at San Diego or elsewhere. It was not found in samples of piling from near tide line at Monterey or Gaviota. It is not at present a factor of much industrial consequence in San Francisco Bay and apparently took no part in the extensive destruction of marine structures in the Upper Bay in recent years. The fact that it completely riddled small timbers and boards at South San Francisco indicates that it has destructive capacities, though the small numbers, large size and heavy weight of its larval stages might limit the rate of its spread.

Destruction of Timber

Data as to this are inadequate as yet, beyond the fact that the settlement on the timbers observed is less dense and the wood far less completely riddled than is wood attacked by *Teredo* in the Upper Bay or in territories adjacent to that in which *T. diegensis* occurred in the bay. It would be unsafe to infer from this that this species would be correspondingly ineffective in other or in all conditions of life.

Teredo navalis Linnaeus*

The Pileworm of Brackish Waters

(Plates 20 to 30)

This is the ship-worm of the dykes of Holland though probably not in all cases the "calamitas navium" of Linnaeus, for another species, *Teredo megotara,* is more often found in the sheathing and timbers of vessels. The precise identity of this species is wrapped in obscurity because of the imperfect descriptions and varying application of the name by early naturalists. The species we find in San Francisco Bay and the one which created havoc in recent times in marine structures corresponds to the one reported to Dr. Calman (1918) of the British Museum of Natural History in a recent publication and in the report of Dr. Redeke (1912) of the Royal Institution for the Investigation of the Sea, as *Teredo navalis* Linnaeus.

This species is the medium-sized species of the three molluscan borers occurring in this region. It is, when full grown in the autumn, from four to ten inches in length, generally six to eight, and the diameter of the head end is from one-fourth to three-eighths of an inch. Its elongated worm-like body is whitish in color, almost translucent towards the outer end, with reddish orange and whitish viscera showing through towards the head or shell-bearing end.

The body lies in the burrow which enters the pile horizontally and generally, but not always, turns downward at once and expands within one or two inches to a nearly uniform diameter throughout the rest of its course. The head, anterior, or shell-bearing end is at the bottom of the burrow with the shell resting against the end or withdrawn or even partitioned off by a shelly membrane in old specimens. The mouth of the burrow (pl. 20, fig. 1) is a minute pore from which the mollusk protrudes its two siphons, and which it closes by means of the two stout pallets attached behind the siphons. This is the posterior end of the body and the end at which water for respiration and food enter and from which the chips from the drilling of the wood and the excreta are removed.

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* Identification based on comparison with specimens from European waters at Plymouth, from Holland, Denmark, and Sweden.

Anatomical Structure

A side view of the body will show the relation of the parts to the activities of the animal. We shall deal only with the more diagnostic features of the structure of *Teredo navalis* since we have already discussed the anatomical structure of *Xylotrya*.

The shell (pl. 29, fig. 1) is similar to that of the other molluscan borers in its form and structure and when full grown is midway in size between those of *Xylotrya* and *Teredo diegensis*. Owing to changes in the shell with growth, wear and age, differences in structure between the shells of this species and those of the other borers are not readily defined and one must turn to the more evident structure of the pallets and siphons for easily used diagnostic characters.

The pallets of *Teredo navalis* (pl. 28, fig. 2) are spade- or paddle-shaped structures each with a short cylindrical stalk connected below the collar with its retractor muscle. The posterior end is deeply concave, and the lateral margins are carried out in acute points which may be worn down to blunt stubs in old pallets. The pallet is blackish towards the tip, but the dark color is reduced in worn pallets. We have found no pallets which have shed the dark periostracum layer as in *Teredo diegensis*. The outer surface of the pallets is convex, the inner somewhat concave, so that when pushed into the orifice of the burrow they slide over and enclose the tips of the siphons.

The pallets of *Teredo navalis* differ from those of *T. diegensis* not only in having less black color but they are also much larger, nearly twice as large in fact, and the connection between the blade and stalk is subconical instead of semi-circular in outline. In some instances, a membrane joins the prongs on the inner face as in the segments of the pallets of *Xylotrya*, but this is absent in old specimens.

In most cases in the examination of freshly split infected piling the pallets may be detected near the entrance of the burrows as prominent white objects visible on close inspection to the naked eye. They are easily demonstrated with the hand lens and when once known afford a ready means of identification of this borer.

The siphons of *Teredo navalis* are also characteristic of the species. They are relatively large, and the contrast in size between the two is greater than in either *Xylotrya* or *T. diegensis*. The anal or dorsal siphon is about half the length and half the diameter, when in a contracted state, of that of the ventral or incurrent siphon. The siphons are both pigmented with scattered blotches of a reddish brown pigment especially near their ends, whereas the siphons of the other molluscan borers are less noticeably, if at all, pigmented.

Life History

Little is known of the life history of this common pest in the face of the fact that it has long been known as an enemy of marine structures. In our own locality we have no definite record of its breeding seasons. Our investigations were started too late in the autumn to detect the limits of this phase of the animal's life in 1920. We only know that it was not carrying larvae in its gills after October 5th, and has not since been found with them. The trend of such fragmentary evidence as we have is that there is an annual breeding season extending over several months in midsummer and that the larvae began settling at Port Costa in July and ceased in October, but these limits are not accurately established and may be exceeded elsewhere at both ends of the period because the varying salinity in our area may have modified our findings.

Evidence of an earlier breeding season is found in data from Crockett furnished by Construction Engineer A. A. Brown from a pile driven in January, 1920, and pulled in May, 1920, when it was found to be infected with *Teredo navalis* and penetrated to a depth of two inches. Since it took two months at Port Costa (under less favorable conditions as to depth and current) to acquire this penetration in August-October, we may conclude that the two inches of penetration at Crockett in May implies a settlement of larval stages as early as April and hence a breeding season beginning in March. In Holland, eggs are found in *Teredo* in June and July and larvae settled from July to September.

It is also probable that it reaches sexual maturity in the first year of its growth. Calman (1919) supports the opinion that it is short lived, dying within the year, or in the autumn, and that only a very few of the adults live over the winter. We have found a heavy deathrate in the autumn associated with falling salinity, and also find in crowded territory near the mud-line that the death rate is wont to be heavy. At Crockett, at a recent examination of piling, live *Teredo* were still found though falling salinity had killed them off in the Mountain Copper Company's experimental piling early in December and at Port Costa in experimental timbers 6 by 8 inches and in a 14-inch pile from the wharf by December 18th. They were all killed in the Shell Company's wharf at Martinez on January 15, 1921. Salinities at Crockett were below 5 parts per 1000 since November 23, 1920, except for flood tides on seven days.

The ova of *Teredo navalis* are reported to be held within the body of the female until they are fertilized by the sperm which are ejected by the male through the dorsal siphon and make their way by chance into the body of the female where they fertilize the ova. These then develop rapidly into free-swimming larvae which are then permitted to escape into the sea. They are supposed to be capable of swimming about for at least a month during which time they develop a foot and a set of bivalve shells (pl. 26, fig. 2). They are then ready to settle down on the wood, and transform into the boring adult type.

The number of ova contained in the body of *Teredo navalis* was estimated by the old Dutch naturalist Sellius (1733) to be 1,874,000. Since, however, the breeding season may extend over several months it is probable that the number of ova produced in the larger females is considerably in excess of this estimate.

During its larval life the young *Teredo* may be carried by tidal or ocean currents for long distances far from its parental home. Hence the ease with which it invades new territories. The length of the larval life is sufficient to permit even a trans-oceanic transfer in the tank of a steamer, or a drift with the current for several hundred miles.

The habit of discharging the larvae into the sea makes every piece of infected timber a potential source of infection of other structures in the route of passing currents and of accidental and occasional dispersal to more distant regions. It is doubtless by some such series of migrations that the *Teredo* of European coasts has found its way to San Francisco Bay, whether by way of the Suez Canal and trans-pacific routes or transpacific currents, or via shipping through the Panama Canal, we can only conjecture.

This migratory habit in the larval period has a direct bearing on the future of engineering treatment of marine structures in San Francisco Bay and especially in that part above the Carquinez Straits. Since *Teredo navalis* is now established in San Fancisco Bay, it is practically impossible to exterminate it, and biologically certain that it will continue to find sufficient wood along the shores of this region to maintain itself. For example, we found bits of river driftwood at Pinole lodged among the shallow water rushes which were shot full of little *Teredo.*

If it can thus maintain itself it is biologically certain that any unprotected wooden structures exposed in San Francisco Bay will sooner or later be attacked and destroyed by this borer. It is equally certain that it has capacities of rapid invasion of newly exposed regions tributary to the bay greatly exceeding those of *Xylotrya* and *T. diegensis.* Should salinities in future years in the Upper Bay rise above 10 parts per 1000, as they did in 1916–1920, the catastrophe of the past year will be repeated, if wood is available for its attack. It is biologically certain that this invasion of San Francisco Bay by *Teredo navalis* has added a new element to the marine hazards which threaten marine structures in this region. It is only a question of time until this pest will appear in other ports on the Pacific Coast.

It is therefore advisable that all engineers in charge of marine structures plant test timbers at favorable locations in their structures and examine them at frequent intervals from April to October to detect incipient attacks by *Teredo.* Heavy infection of such timbers would mean infected piling in the neighborhood.

Burrows

The tubes or burrows of *Teredo navalis* differ from those of *Xylotrya setacea* and *T. diegensis* in our timbers in being smaller than the former and larger than the latter and somewhat more thickly set or crowded than either. They enter the piling less deeply than *Xylotrya,* whose burrows, whether few or many, are wont to enter the pile even to the center, while *Teredo* enters deeply by reason of crowding. Moreover, *Xylotrya* works in shallow water less readily than *Teredo.*

The maximum length is not often in excess of twelve inches and the maximum diameter one-fourth or five-sixteenths of an inch. When crowded the burrows are often only one-eighth of an inch in diameter. The burrows enter by minute holes 0.008 inch in diameter when first made but enlarged to as much as 0.03 as the animal grows older. This outer end enlarges rapidly within an inch of the orifice to accommodate the pallets and collar. The burrow runs a curved or straight course, often with the grain and downwards when not crowded, or more or less obliquely across it when crowded (pl. 20, fig. 2).

The burrows twist and turn to avoid crossing each other and the direction of the tube may even be abruptly reversed in a short turn, or the inner end abandoned and a new course established at a point above it (pl. 26, fig. 2). The burrows are subect to minor deviations in direction but not to the degree found in the tubes of *Xylotrya* and *Teredo diegensis.* They are generally straighter or more regularly curved, and have smoother walls. The burrow is lined with a thin wall of nacre which scales off readily. It has no cross ridges or middle partition as in that of *Teredo norvegica.* We have not found it forming stout calcareous tubes as the wood is eroded by *Limnoria* or other causes, though a heavier calcification of the outer tip of the burrow may occur. The smaller size of the pallets of this species as compared with those of *Xylotrya* makes any enlargement of the opening a dangerous matter for this species.

The settling of the larval stages upon the timbers is quite variable in density and location on the pile. The following factors appear to be operative in determining the location: (1) The weight of the larval stage due to the growth of the shell tends to increase the numbers near the bottom as they settle from the plankton. Hence, the pile at and just above the mud-line is most heavily attacked and most quickly and completely penetrated, thus leading to the breaking off of the piling at the mud-line. They extend upward on the pile to within a foot or less of the barnacle line or to a little above mean tide level. (2) The set of the current with reference to the sources of infection and its rate of movement combine to determine the relative numbers settling on upstream and downstream faces, or off- and inshore sides. At Mare Island dike, the upstream and offshore face against which the current plays more rapidly was the one more heavily attacked and more deeply penetrated (pl. 23, fig. 1). At Port Costa, the faces next the current were also more heavily set on experimental timber (pl. 27) and more deeply penetrated. At Martinez, owing to some undetermined feature of current or source of infection, it was the easterly side of the piling which was more rapidly penetrated. (3) There is a noticeable irregularity of distribution of the settling of larvae on the surface of the wood and one often finds what appear to be centers of settlement from which the tubes radiate into the wood while adjacent surfaces will be thinly set if at all. There is a possibility that these local differences have their origin in differences in the amount and quality of the extractives from the wood to which the larvae are sensitive, with the result that they are drawn to certain areas more than to others. These areas bear no fixed relation to knots or other structural features.

The number of larvae settling on a given timber is subject to many variations and the only limit in number appears to be the available surface. Mr. Mattos reports having counted 347 on a single square inch. In heavily infected timber with close set tubes we find as high as twelve in a linear section of one inch but in general the number of tubes in a square inch is not often in excess of 25–50.

The degree of destruction of the timber by excavation is a function of the density of settlement and penetration. In piling with a fairly heavy infection from Port Costa, we find on measuring the volume of the excavation by the alcohol displacement method that four samples gave the following result:

	Total volume, ccm.	Volume of excavations, ccm.	Per cent excavated
1	135	67	49.4
2	118	44	37.3
3	107	39	36.4
4	90	53	59.8

The average per cent excavated in these samples was 45.5 per cent. In densely attacked timber, the percentage of excavation will run somewhat higher than these figures.

Rate of Growth

The rate of destruction by the burrows of *Teredo navalis* is a function of so many variables that any determination of the rate is valid only for the particular combination of variables at the point of determination. These variables are the density of the attack, the food supply in the plankton, temperature, salinity, current and depth, season of the year, and a host of minor conditions.

It will suffice for our purposes to cite several instances from timbers of experimental planting. Rough and dressed timbers of Oregon fir six by eight inches were planted in 18 feet of water in the Port Costa wharf on April 2nd and May 5th, 1920, by Mr. Mattos of the Southern Pacific Company, and were found on August 4th to be lightly infected (in salinities averaging about 20 parts per 1000). On August 16th, the infection was heavy, averaging 130 per square inch, the pits having a diameter of 0.008 inch and were only deep enough to accommodate the minute shell of the young borer (pl. 26, fig. 3). On August 26th, the opening had increased to 0.01 inch and its depth to three thirty-seconds, while its diameter below the surface increased abruptly to one-sixteenth inch. The salinity during this period had reached 25 parts per 1000.

On September 15th, another examination was made in salinities of 28 parts per 1000. The orifices of the burrows had enlarged to 0.013 inch, and growth had been very rapid. A few of the larger borers had attained a length of 1.3 to 1.8 inches but the great majority were only 0.40 to 0.65 inch. The settlement of larvae and the growth of the borers continued rapidly, especially near the mud-line into October, when larval settlement slowed up. On September 25th, the penetration was 1.5 inches in the highest salinity of the year, 29 parts per 1000.

On December 8th, these timbers were examined, and also some others planted July 1st. All were found to be heavily infected and several broke of their own weight at or near the level of the mud-line when lifted upon the wharf. Sections of timber No. 4, planted July 1st (pls. 21 and 27) show that at the mud-line the 6 by 8 inch timber had been completely riddled by *Teredo*. This timber had been examined on August 4th and showed no infection at that time. In four months or at the most 126 days, this timber was destroyed at the mud-line. A similar attack on a 12-inch pile would penetrate three-fourths of its cross-section and reduce its efficiency below the danger line. Substantially corroborative results were obtained on experimental timbers exposed by Mr. O. K. Smith on the wharf of the Mountain Copper Company at Martinez, three and one-half miles above Port Costa, except that the rate of penetration was somewhat less rapid.

At Crockett, Mr. Brown found that a pile driven in the latter part of January, 1920, and pulled three and one-half months later in May, had a penetration of two inches (pl. 25, fig. 2). This undoubtedly resulted from the spring set of larvae upon the opening of the breeding season. He reports that in redwood salt water tanks on the ninth floor of the refinery at Crockett in July-September, 1920, *Teredo* penetrated the redwood lumber two inches in eight weeks.

Distribution

Teredo navalis has long been known from European coastal waters. It attacked the dikes of Holland in 1730–1732, 1770, 1827, 1858–1859 during periods of reduced rainfall when unusually high salinities invaded the Zuyder Zee and the coastal waters of Holland. It is reported by Calman (1919) as causing damage in the estuary of the Thames and on the east coast of Great Britain and by Redeke (1912) as extensively distributed in piling in Dutch harbors.

In so far as records and literature are available no evidence exists to show that *Teredo navalis* has ever heretofore been found on the Pacific Coast, at least on the California coast. Dr. W. H. Dall, the veteran conchologist of the United States National Museum and a life-time student of the Mollusca of this coast writes me that it is unknown from the Pacific Coast. The species reported by A. L. Barrows (1917) from Mare Island on the identification of Dr. Bartsch as *Teredo diegensis* is undoubtedly the same one at work there at present, namely *Teredo navalis.*

The pallets of the species prevalent in San Francisco Bay are identical in structure with those of the species figured by Calman (1919) of the British Museum and by Redeke (1912) of the Royal Institution for the Investigation of the Sea in Holland as *Teredo navalis.* These two men are the only recent European investigators of this species. We conclude, therefore, that the devastating species of San Francisco Bay is the same one which has created havoc for centuries past in European waters. Moreover, the conditions under which it became so destructive were similar in those waters and in our own, namely, reduced rainfall, invasion of waters of higher salinity into areas previously less saline and the rapid multiplication of the borer with resulting destruction of great quantities of exposed marine structures.

The name "shipworm" as applied to *Teredo navalis* is somewhat of a misnomer, for another species, *Teredo megotara,* is found in wooden vessels in Dutch waters, while *T. navalis* occurs more especially in piling and is more properly called the "pile worm."*

We have been unable to determine when and by what route *Teredo navalis* reached our shores. The pile-worm present in San Francisco Bay during the investigation by Engineer Armstrong of the United States Forest Service and myself in 1910–1911, was solely *Xylotrya setacea.* Specimens of the piling destroyed by them at that time show no traces of attack by *Teredo navalis* or *T. diegensis.* If *T. navalis* was present during that investigation it entirely escaped detection. It seems probable either that it was present in such small numbers and restricted distribution that it was of no industrial consequence, or that it is a newcomer to our shores. In support of the latter conclusion is the fact that it has never heretofore been found by all the shell collectors who have scoured our shores for more than half a century. The biological survey of San Francisco Bay in 1912–1913 by the United States Bureau of Fisheries and by the University of California did not bring it to light.

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* The name "pile worm" is often misapplied locally to a reddish, segmented annelid worm (*Nereis*) which lives in crevices and abandoned burrows of *Teredo* in piling.

It was first found, as reported by Barrows (1917), in January, 1914, by the naval authorities at Mare Island in the outermost end of the long dike, especially on the eastern or upstream face, and in the exposed brace piling of the dike where it had eaten the brace piling half way through and penetrated the sheet piling for an inch. This damage followed two low water years of 1912 and 1913 and was evidently the result in part of the summer infection of 1913. It was also brought to light at a wharf a mile above Vallejo Junction in the spring of 1914 when a steamer rammed the wharf and it was found that the broken piling had been damaged at the mud-line by "teredo." It is probable that this damage in 1914 was due to *Xylotrya* rather than *Teredo.* We have been unable to locate any material to confirm the identification as *Teredo.*

A repetition of the damage by *Teredo* was found in January, 1917, on the outermost dike at Mare Island after three years of higher water. The penetration was about three inches at a maximum and the damage was not so serious as in 1913–1914. In January, 1917, borers were also found by Engineer A. A. Brown in the piling of the California-Hawaiian Sugar Refinery at Crockett. They were relatively few in numbers, were mainly near the mud-line, and had a maximum penetration of about four inches. This refinery stands close to deep water and the current of the channel at the narrow part of Carquinez Straits in a location particularly favorable for the settling of the larvae and the rapid growth of the borers.

Fortunately Mr. Brown is able to supply evidence that the borers' attack at Crockett in 1917 was by *Xylotrya* and not *Teredo.* He reports that they worked exclusively in the deeper waters above the mud-line, that they had large burrows and the jointed pallets characteristic of *Xylotrya.* These borers were found also in 1918 at Crockett and it was not until 1919 that the smaller tubes of *Teredo* working in shallow water as well as the deeper water were detected. The attack was relatively light in 1919 but came on in full force in 1920. Xylotrya still persisted (pl. 25, fig. 1) at Crockett in small numbers during the *Teredo* outbreak and there are burrows in photographs of Mare Island piles full of *Teredo* which look like those of *Xylotrya* (pl. 23, fig. 1).

It is quite possible that the *Xylotrya* infection at Crockett came with a raft of 3500 green piling rafted down the coast in 1915 to the pile boom at Islais Creek and thence to Crockett, where they were driven in the period from January to June, 1917. Some burrows were detected at that time in these piles when cut off in connection with the driving.

In December, 1919, it was found that in the piling of the Southern Pacific slips at Port Costa and Benicia *Teredo* had penetrated the piling two to three inches and in some instances had almost completely eaten the pile through at the mud-line. A pile pulled at Vallejo Junction in June, 1919, and sawn in two-foot sections did not contain *Teredo,* nor was it found in surface sampling at low tide on Southern Pacific structures in the upper bay in June, with surface salinities of 3.3 parts per 1000, but was detected in great numbers on October 15, 1919, in surface and bottom salinities of 22 parts per 1000, at Vallejo Junction when a steamer broke off some piling, and shortly thereafter at Port Costa and Benicia, in surface salinities of 12.1 and bottom of 17.6 parts per 1000, in pulled piling. In March, 1920, they were actively at work in the wharf of the Mountain Copper Company at Martinez where they had penetrated the piling for one-half an inch. The flood waters of April-May exterminated the borers and mussels at this wharf by June 1, as shown by the examinations of Mr. O. K. Smith. By the autumn of 1920 they spread up stream until they had reached Antioch on the San Joaquin, 25 miles above Carquinez Straits and 50 miles from the Golden Gate, and up the sloughs of the Delta to Dutton. Reports that they had reached Rio Vista have not been verified by actual specimens.

This progressive invasion was the direct result of the continued shortage in the annual rainfall and run-off during these years, which permitted the settling of the larval stages on unprotected piling during the breeding season of midsummer and the survival of the borers in the wood during the brief season of the spring freshets of these years. In the upper bay from Pinole through Oleum, Mare Island, Vallejo, Crockett, Port Costa, Benicia, Martinez, to Mococo and Avon, the destruction of piling by this *Teredo* in the summer of 1920 reached a climax which left little or no untreated piling undamaged and not a little of it wholly destroyed by penetration to the center or near it, at the mud-line. See plates 2 and 24 illustrating the work of the *Teredo* in the wharf of the Shell Oil Company at Martinez. Above Mococo the attack was very widespread but owing either to the brevity of the attack or to the adverse conditions of less salinity, the penetration was not so deep and the growth of the borer less rapid so that the destruction did not attain there the level of a commercial catastrophe.

In the mean time the invasion had spread elsewhere to unprotected structures, such as those above Black Point on Petaluma Creek, to the wharves at Richmond, and to the unprotected piling of the dolphins of the Alameda Mole, to some points in the Oakland Estuary, to the Bay Farm Island Bridge, and to the Dumbarton Cut-Off at the southern end of the bay. It was also found during our survey at South San Francisco, in the Bay View sewer outlet, and at the sewer outlet at Hunter's Point, in new piling in the boom at Islais Creek, and sparingly at Pier 7 on the San Francisco waterfront in treated piling which had been opened up by the attack of *Limnoria*. From the distribution thus shown it is to be inferred that all unprotected piling in San Francisco Bay may be expected to show upon examination an attack by this borer.

Relation of Salinity to the Occurrence, Distribution, and Persistence of Teredo navalis

The factor of salinity is one of fundamental importance in the distribution of *Teredo navalis*. The records of its occurrence elsewhere, notably of its recurrence in the dykes of Holland at intervals since 1730 at times when subnormal rainfall and run-off increase the salinity in the coastal waters, all combine to indicate that this species is one especially adapted to the invasion of new territory under just such conditions as have prevailed since 1912 in our own locality.

It is clearly a species surviving a wide range of varying salinities and thus capable of appropriating promptly tidal areas which the sea is tending to invade whenever decline in run-off extends the marine faunistic area.

As a result of his investigation of the *Teredo* outbreak in 1914–1917, Barrows (1917) concluded that "It seems probable, therefore, that *Teredo diegensis* [our *T. navalis*], once established, can withstand for several weeks or perhaps months a reduction of salinity to about 10 parts per 1000, though perhaps thriving sufficiently to cause marked damage only in a region where the salinity of the water, except for a short period, must average at least 13 or 14 parts per 1000." It has thus far survived the drop in salinity at Crockett in December, 1920, to less than 10 parts per 1000 though now exterminated at Mococo, Martinez and Port Costa (pl. 36). On January 14 a pile examined at Crockett had a number of the larger *Teredo* in the center of the pile still in normal condition, but the smaller ones in the outer part had been killed off.

It is unfortunate that we have no series of annual seasonal records at any station in the area of the outbreak of *Teredo* covering the years prior to 1920 for the purpose of determining the lowest limit of salinity at which *Teredo* entered the new territory or the salinity and period of exposure thereto, by which it may have been exterminated temporarily.

We have, however, a check in that we can relate the second-foot discharge of Table I (Hydrographic Section) for flood years of normal discharge, and the low water years of 1911–1912, 1912–1913, and 1918–1920 to our salinity records of 1920 (pl. 36). We find, for example, that salinities in April-May, 1920, at Vallejo Junction at flood tide averaged close to 7.5 parts per 1000. This is close to the supposed toleration level of salinity for *Teredo navalis.* It corresponds to a summation discharge in these months of 29,820 and 24,218 second-feet. In a normal year, the six months from January to June inclusive practically exceed these amounts of discharge and the contiguous month of December runs high (17,300) so that for at least seven continuous months of the normal year, *Teredo* would have unfavorable conditions above San Pablo Bay. This period of time is presumably long enough to exterminate the hardiest *Teredo* completely.* The remaining five months of the normal year have a discharge of less than 12,000 second-feet. This is a continuous period and coincides with the breeding season of *Teredo,* at least from July to October. In June, 1920, the discharge was 10,984 second-feet and the salinity at South Vallejo averaged about 12 parts per 1000. This was a favorable season for the settlement and growth of *Teredo navalis.* In 1920, we found experimentally that this is sufficient length of time to permit at least three inches penetration of piling provided there is a supply of larvae for settlement. It therefore appears that *in normal years* the period of low discharge is accompanied by a salinity at Carquinez Straits quite within the limits of toleration of *Teredo,* from July to November inclusive, and that given a source of infection *Teredo* may be expected to return in the future even in normal years and to be capable of doing considerable damage above Carquinez Straits before the winter floods can suppress its activity and ultimately exterminate it. In 1919 and 1920, it survived in this territory or at least returned to it with destructive force after 5 and 3 months respectively of discharge in excess of 12,000 second-feet, or salinities below 12 parts per 1000, and of four and two months in excess of 20,000 second-feet, or salinities approximately below 7.5 parts per 1000. We may infer from these data that it is probable that *Teredo* will return to the Upper Bay in the summers of normal years with destructive force and that the degree of destruction will be determined by the extent of the supply of larval stages, which in turn is dependent upon the amount of infected piling in the region tributary to the tidal currents.

We also have another check on the situation in the very complete and valuable records of the California-Hawaiian Sugar Refinery at Crockett kindly furnished by Construction Engineer A. A. Brown. These data constitute a record of the activities of the water barges bringing fresh water down stream for the refinery. The records show from January, 1908, to July, 1920, inclusive, the distance traveled (round

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* A few *Teredo* at Crockett have lived through the winter of 1920–1921 in water frequently below 1 part per 1000. (Note added August, 1921.)

[illegible] shows clearly that from August, 1911, to January, 1914, were only two brief intervals when the salinity fell below 7.5 s per 1000 (as measured by 12 miles per trip). These intervals e May (8.9 miles) and June (7.2) in 1912, and April (9.9), May

(7.2) and June (10.5) in 1913. It is well within the range of probability that the larger *Teredos* could survive these periods especially in view of the fact that depression in salinity (miles per trip) in these periods was relatively slight. However, in 1914, 1915, and 1916, there were periods of 6, 4, and 6 months respectively in which the salinity (miles per trip) was very much depressed. It is practically certain that *Teredo* could not have survived above Carquinez Strait during the interval represented by any one of these periods. Any summer infection in piling above this point would be relatively light because of the then absence of large breeding grounds down stream (except possibly in the outermost part of the Mare Island dike) and the floods of the succeeding winter would probably wipe it out. It thus seems highly probable that during the interval from January, 1914, to July, 1916, the up-stream invasion of *Teredo navalis* was held in check by hydrographic conditions as represented by the amount and duration of the run-off.

With the beginning of July, 1916, through February, 1917, there was a period of salinities in excess of 10 parts per 1000 (above 12 miles per trip) at Crockett during which borers could settle and thrive. This coincides with the first finding of *Xylotrya* in piling at Crockett by Mr. Brown, who discovered a few with burrows four inches in length. Penetration to this depth by *Teredo* was accomplished in experimental timbers at Port Costa in 1920 between July 1st and December 8th.

With the return of low water and higher salinities in July, 1917, there follows a period extending to October, 1920, within which the salinities (distance travelled) ran high continuously except for March-May, 1919, and February-May, 1920, with a record of 11.1 miles for February of that year, so that in reality there were only three months in each of those years in which the salinity was below 7.5 parts per 1000 (12 miles distance) and in neither year did it reach the very low levels of ordinary flood season in these intervals. It is therefor highly probable that the conditions approached closely toleration levels and in the lower part of the invaded territory that many *Teredo* survived these conditions. Construction Engineer A. A. Brown of the California-Hawaiian Sugar Refinery reports *Xylotrya* living in their piling throughout these periods, *Teredo* appearing with certainty in 1919.

During the remaining 29 of the 35 months in the period from July, 1917, to November, 1920, the salinities were in excess of 7.5 parts per 1000 (12 miles per trip) and in 25 of the 35 it was in excess of 12 parts per 1000 (17.5 miles per trip). Ideal conditions were therefore prevalent in the Upper Bay for the multiplication, settling and growth of the molluscan borers from July, 1917, to November, 1920, with the exception of two intervals of three months each within which these borers had at least a fighting chance to tide over the conditions of lowered salinity.

One other conclusion bearing upon the grounds for and source of the extraordinary outbreak of 1917–1920 results from our survey of the distribution of *Teredo navalis* in San Francisco Bay and the chronology of the outbreak.

It was evident that the outbreak of 1912–1913 at Mare Island was a new one. There were no records of borers at that place prior to that date. There has been no record of *Teredo navalis* on the Pacific Coast prior to that date. It was an extensive infection spreading over 6000 feet of the outer end of the long dike at Mare Island especially on the outer face next to the current, the brace piling being half eaten through. Renewed activity was again noted in the spring of 1916 and winter of 1916–17, and in 1919 they were first detected at the sugar refinery at Crockett.

These facts should be considered along with the results of our survey of the rest of the Bay Region. *Teredo navalis* now occurs throughout most of San Francisco Bay from Richmond as far south as Dumbarton Cut-Off. Though it was not found at all points, especially when freshly pulled piles were not available, it was nevertheless so widely distributed that it is to be expected today in unprotected timber exposed anywhere in the bay. It was a very striking feature that this infection by *Teredo* wherever found south of Black Point and Pinole was relatively light as compared with the extraordinarily heavy infections from Mare Island to Avon in the Upper Bay. This relative scarcity of *Teredo* in the lower bay leads us to conclude that either *Teredo* does not thrive in the higher salinities of that region or that the territory is not yet fully seeded. In either case, the conditions support the inference that the *Teredo* of the lower bay is not and has not been the source for the heavy seeding of the Pinole to Avon section of the Upper Bay. There are too few of them.

On the other hand, the heavy initial infection in 1912–1913 in the 6000 feet of piling of the Mare Island dike was a source of infection to all parts of the bay washed by the tidal currents passing that structure. The recurrence of the destructive activity of the borers in 1916 suggests that the infection lingered there or in that neighborhood and that this extensive structure of unprotected piling alongside the main tidal current has been and still is the principal source from which the adjacent territory and possibly the whole bay has been seeded.

The Crustacean Borers

In addition to the three species of molluscan borers attacking marine structures there are three others belonging to the Crustacea of general distribution, namely *Limnoria, Sphaeroma,* and *Chelura.* The first two belong to the sub-order *Isopoda,* which are Crustacea with dorso-ventrally flattened bodies living in the sea, in fresh water and on land in moist localities. This sub-order includes the wood lice, pill-bugs, and sow-bugs of our gardens and wood-piles.

The third Crustacean borer, *Chelura,* belongs to the sub-order *Amphipoda,* with laterally compressed body. This sub-order includes the sand hoppers, sand fleas, and numerous small crustaceans found in the margins of reservoirs, on beaches and in the littoral marine fauna.

Limnoria and *Sphaeroma* only have been found as yet in San Francisco Bay. These borers owe their efficiency as destroyers of wood to their powerful biting jaws by which they cut their way into the hardest of wood. They both belong to types of crustaceans adapted to life in the zone of extreme environmental conditions, between tides where moisture, light, salinity, temperature, food supply, and stability of the substrate are subject to rapid and extreme change. They are therefore of hardy stock inured to withstanding hard knocks and awaiting the return of favorable conditions.

They have both adapted their mode of life to these extremes by digging into wood for shelter and have thus come to be enemies of man's marine structures and, in the case of *Limnoria,* to have acquired a wide distribution throughout the harbors of the world.

Limnoria lignorum (Rathke)

The Gribble

Plates 31 to 34

Anatomical Structure

The body of this borer is small, the largest individuals attaining a length of a quarter of an inch and one-third as wide. it is elongate slipper-shaped, flattened dorso-ventrally and has rounded ends. The head is not constricted from the trunk by a neck and the thorax is not differentiated from the abdomen. The head is bluntly rounded and the tail or last segment of the abdomen is a subcircular structure which can be tilted up as a thorny door to close the burrow against intruders. The body can be rolled up into a ball as in *Sphaeroma.*

There are two pairs of antennae and seven pairs of ambulatory legs. On the under side of the head there are four pairs of mouth parts, a pair of stout biting mandibles, two pairs of maxillae, one with a toothed end, and a pair of maxillipeds, all adapted to assist in the tearing up of the wood.

Life History

On the under side of the body between the legs the female has a brood pouch in which the eggs are carried during their development.

These eggs are large, nearly one-fourth the width of the body in diameter, and when the young are hatched out they are ready at once to begin the burrowing process near the parent. There is no free-swimming larval stage, no period of forced migrations, and little risk of destruction. Few young are produced and these are ready at once to dig in for themselves. For this reason, the spread of *Limnoria* is like the growth of a lichen or the spread of the mange or itch. The colony grows at the periphery (pl. 33, fig. 1) and burrows constantly deeper into the wood.

We have no precise data as to their breeding seasons and length of life. Young and eggs are found throughout the year, though it is probable that reproduction is more rapid during the warmer season. The two sexes are much alike in appearance and differ only in slight anatomical details. We have found about the same number of males and females. A single square inch of infected Douglas fir from Tiburon heavily-attacked by *Limnoria* was found to contain 79 females, 33 of them with eggs attached, 82 males, and 221 young in various stages, a total of 382 individuals.

It is probable that the breaking away of fragments of infected wood, the wash of tidal waters and the occasional wanderings of individuals provide for the spread of infection by this borer from timber to timber in marine structures, and that the movement of infected driftwood and shipping suffices to account for its world-wide distribution.

Distribution

Limnoria is found on both the Atlantic and Pacific shores of the United States, north to Bering Island, and has been reported on European coasts from the Adriatic to Norway. It is common along the California Coast in piling on the ocean front. In San Francisco Bay it is very destructive in the Golden Gate, on the Oakland and San Francisco water fronts, at Dumbarton Cut-Off and at Sausalito, Tiburon and Richmond. It was not found north of San Quentin and San Pablo Point and took no part in the invasion of the Upper Bay with *Teredo*. It is thus abundant where salinity is not much reduced by fresh water. It is possible that its slow method of distribution prevented its entering the Upper Bay and that in time it would enter that region in the salinities present during the past year. *Limnoria* seems to thrive in sewage-laden waters. It was found at Hunter's Point and Islais Creek at the mouths of sewers and at Pier 7 on the San Francisco waterfront, where it was particularly destructive of creosoted piling near the mouth of a large sewer. It was also doing heavy damage in Oakland Estuary where the water is polluted by sewage and industrial wastes.

Destruction of Piling

Limnoria destroys piling by gnawing its interlacing branching burrows into the surface of the wood. We have found from 200 to 240 burrows per square inch in heavily attacked timber. These burrows are from 0.050 to 0.025 inch in diameter and follow the softer zones of spring growth between the more resinous harder zones of the annual rings. Piling infested by *Limnoria* thus has an outer scurf of one-eighth to three-sixteenths, rarely three-quarters inch of perforated somewhat laminated wood which is readily broken or falls away as the attack proceeds. In square timbers the attack progresses rapidly between the harder zones of the annual rings on radial sections, leaving these resinous strips as projecting ribs.

Limnoria works at all levels in harbor waters from near the mudline to the uppermost tidal level with great facility. It whittles away piles until they are reduced to axial skeletons with the harder, more resinous knots projecting therefrom. It is, however, most active between tide levels, cutting off piling below mean tide level or reducing them to an hour-glass shape there more rapidly than it erodes at lower levels. *Limnoria* works up nearly to the highest tide level. At Pier 7, it was found in corbels on the top of piles which were only partially submerged at high tide, and had found its way from the untreated corbel down into the creosote-free heart wood of a treated pile (pl. 9).

This borer is particularly insidious in its attacks upon creosoted piling because of its habit of creeping into small crevices. If cracks open through the saturated zone of a creosoted pile or if bolt or dog holes or peavey holes or other breaks in the continuity of this protection occur, *Limnoria* is sure to find its way into the retreat thus offered and to begin its destructive work. It will reduce such a pile to a mere shell. It is sometimes found in such piles actually at work in the creosoted zone itself. Whether it does this because it slowly becomes acclimatized to the repellant substance or because of defective creosoting, low grade oil, or progressive leaching out of the toxic elements of the oil, is unknown. It is possible experimentally to acclimatize animals to live in toxic solutions by gradually increasing the dose, until they will thrive in solutions originally deadly to the species. *Limnoria* working near the creosoted zone might be thus acclimatized to the creosote. Since *Limnoria* may gnaw away the wood without eating it, it is also possible that it might for this reason be able to extend its destructive action into toxic territory for some distance. Ordinarily its digestive tract is found to be filled with the fragments of wood which seem to serve as its food.

The proportion of the wood removed by *Limnoria* in its burrows is somewhat less than that removed by *Teredo*. *Teredo*-eaten piling has a firmer consistency because of the thicker partitions between the burrows. *Limnoria*-eaten wood is more friable or spongy because of the numerous small burrows and the more or less elastic resin zones left somewhat intact by these borers.

A test by the displacement method in alcohol of the amount of excavation in a piece of Douglas fir squared timber eaten by *Limnoria* from Tiburon gave the following results:

	Volume of sample, ccm.	Volume of excavation, ccm.	Per cent excavated
1	3.5	1.1	31.4
2	3.4	1.3	38.1
3	2.5	1.0	40.0
4	2.5	0.9	50.0
5	1.8	0.5	54.5

The average of the five was 42.8 per cent. The considerable number of borers remaining in the burrows somewhat reduces the apparent volume of the excavation. The probability is that it is often in excess of 40 per cent.

The rate of destruction of marine structures by *Limnoria* varies with many factors, among them the harbor conditions as modified by sewage and industrial wastes. Its ravages are severe on the ocean front on the California Coast and in the Golden Gate. Its destructive action is more variable in different localities in San Francisco Bay. It attacked creosoted piling in the Dumbarton Cut-Off, causing locally, presumably at points of damage to the creosoted zone, serious damage in twelve years. It destroys eight-inch untreated piling (in conjunction with *Xylotrya*) on the Golden Gate waterfront in eight months and untreated fender piling in the Oakland wharves in six months to two years.

The brace piling of the Oakland Municipal Wharf on the Estuary is differentially attacked with reference to the outlet of the Grove Street sewer. Above this sewer the attack is severe, while below it the piling is not seriously troubled by borers. The refuse of the gas works adjacent to the sewer with its toxic qualities may be the potent influence in causing the difference. Above the sewer, the 12 to 15 inch untreated brace piling of Oregon fir lasts from six months to two years. Accidents and damages near the mud-line by *Xylotrya* (pl. 14) combine with *Limnoria* to shorten the life of these piles, but *Limnoria* is an effective agent in the rapid reduction in diameter of the piles.

Sphaeroma pentodon Richardson

The Pill Bug Borer

Plate 35

Anatomical Structure

This crustacean borer is a larger, stouter form than *Limnoria*, but with the same general structure. The body is broadly ellipsoidal in outline seen from above with rounded ends. It is one-half inch long and one-quarter inch wide and rolls up into a ball about a quarter of an inch in diameter when disturbed. Its color is dark olive to slightly reddish brown. It is often mottled or blotched with lighter dull yellowish areas on the middle of the back. The eyes are prominent and lateral in position. The surface of the body is minute and finely granular. The posterior segment is evenly rounded in outline and bears on its median surface two subparallel rows of four tubercles each, and there is a prominent transverse elevation across its posterior border. The outer mobile branch of the last pair of appendages of the abdomen bears five posteriorly projecting teeth which serve the useful purpose of laying hold of the sides of the burrow and pushing or holding the head and gnawing mouth parts firmly against the bottom of the burrow, and also of summarily ejecting any intruder into the burrow who ventures within reach of this end of its occupant.

Life History

Nothing is known of the development or breeding habits of this species beyond the fact that the ova are carried on the abdomen of the mother for a time and that the young ones are found in late summer and fall in the burrows with the adults.

Sphaeroma is very often found in crevices or other sheltering nooks outside of its burrows and is evidently something of a forager. It does not appear to depend upon the wood eroded from its burrow for food, for its stomach contents are made up of the minute vegetable and other growths which cover the surface of the piling. We have found fragments of wood in the intestine, not in quantity sufficient to indicate that it habitually feeds on the wood. This observation is correlated with the fact that the burrows are often shallow and may offer no evidence of recent burrowing activity on the part of its occupant, and that it often burrows in the mud.

Burrows

The excavations made by *Sphaeroma pentodon* in marine structures are very characteristic in size, distribution and location. They have circular openings up to nearly one-half inch in diameter, enter the wood horizontally or turn more or less abruptly and run with the grain in the softer layers of the wood. They do not exhibit the expansion characteristic of the molluscan burrows.

Sphaeroma works mainly between high and low tide, though found at all levels on piling. Its workings are obscured (pl. 11, fig. 2) in deeper water by the more intense activities of *Limnoria* and the growth of other marine organisms. Between tide levels it gives to the piling a pitted appearance with its large, open, dark-colored burrows. Its work is erratic in that often only certain piles are subject to its attacks while neighboring ones may be untouched.

It sometimes runs channels on the surface of wood, especially in the more deeply submerged piling.

Barrows (1919) has found this species burrowing into tuff and friable sandstone at Rodeo on San Pablo Bay, where they excavate burrows ranging from 2 millimeters long and 6 millimeters deep occupied by young individuals, up to burrows 9 millimeters in diameter and 35 millimeters deep. They also excavate holes with great enterprise in chalk when placed in aquaria under observation.

They are hardy ubiquitous creatures finding a home and ''digging in'' into a great variety of substrates, such as soft mud, wood, or even rock itself. They dig for shelter rather than food and except in a few restricted localities are industrially of less consequence than any of the other borers we have discussed.

Distribution

Sphaeroma pentodon has a wide range of distribution in our locality. It has been found at Sausalito, Tiburon, Black Point, the Mare Island dikes, in Napa Creek, along Carquinez Strait and upstream to Antioch in water of low salinity. It also occurs along the western water front and Oakland Estuary and in the southern part of the bay to South San Francisco and the Dumbarton Cut-Off. It is known to occur northward to Alaska.

Its close relative, *Sphaeroma destructor* Richardson, is known to attack piles in fresh water in St. John's River, Florida, where in eight years it reduced piles from 16 to 7½ inches in diameter.

There is a closely related isopod crustacean, *Exosphaeroma oregonensis* (Dana) found in the same localities with *Sphaeroma pentodon* even in its burrows, which is readily mistaken for *Sphaeroma*. It differs from the wood-boring crustacean in the absence of the row of five teeth on the outer branch of the last pair of abdominal legs. The wide spread occurrence of *Exosphaeroma* in crevices and channels on pilings lays this species also open to suspicion as a wood borer but, as yet, the evidence that it is a pest of industrial significance is inadequate to settle the matter finally.

Chelura terebrans Phil.

The Feathered Crustacean Borer

Pl. 35, figs. 1–4

The body is not as much laterally compressed as in most Amphipoda and is more nearly subcylindrical so that it is adapted to the burrows it makes in the wood. The body at the segmental joints, the antennae and the legs are heavily feathered throughout by long hairs.

Chelura can be at once distinguished by the presence of a stout, curved, pointed spine projecting from the third abdominal segment at the posterior end of the body on the dorsal side. The terminal segments of the last pair of abdominal legs are highly modified as two long, stout, smooth, club-shaped structures nearly half as long as the body which project posteriorly and serve to block the burrow to intruders, in the male.

Chelura works with *Limnoria* in marine structures and excavates burrows in much the same fashion. It may easily be overlooked in such circumstances.

Distribution

Chelura has not been found by us in the survey of San Francisco Bay nor in piling from Monterey, Santa Barbara, or Gaviota. We have not been able to find any record of its occurrence in the Pacific Ocean.

It is known as a wood destroyer in European waters from Norway to the Black Sea, and on the Atlantic Coast of North America. The Panama Canal and the increase in round-the-world and interoceanic shipping increase the probability of its appearance on the Pacific Coast.

BIOLOGICAL INDICATORS OF TEREDO

The crustacean borers work upon the surface of submerged wood and leave an open record of their destructive activities in the erosion caused by their burrows. *Limnoria* and *Chelura* erode so rapidly that few other forms of marine life can obtain, or long retain a foothold on the wood in which these borers are working.

In the case of the molluscan borers, the case is different. They enter the wood as minute larvae and leave only a pinhole to mark the places. There is nothing to indicate to the casual observer either their presence or the degree of destruction which they have accomplished. The closest inspection with the hand lens is generally necessary to reveal the minute openings into the wood.

There are, however, certain forms of marine life, easily identified and quickly recognized, and of very cosmopolitan distribution in most of the harbors of the world which may be used as indicators of suitable conditions for the occurrence of the marine borers, especially of *Teredo navalis,* in territory recently invaded by waters of higher salinity as in Carquinez Straits.

Our survey of the Sacramento River to Sacramento brought out the fact that certain forms of marine life had gone up the river as far even as Walnut Grove, and that these same forms were luxuriantly thriving on piling attacked in Carquinez Straits as salt water had invaded that territory. They serve, therefore, as indicators to the uninitiated that the sea with its fauna is invading new territory. These marine organisms are the barnacles (pl. 20) and the hydroids (pl. 32). The former are well-known crustaceans encased in an armor of shelly plates which cover piling, rocks, ships' bottoms, and any available substrate with hosts of more or less close-set, whitish, angular bodies ranging up to a hazel-nut in size. The hydroids are moss-like plant-animals which form a grayish or brownish mass or when dead, hair-like growth over piling. Many small crustaceans will be found creeping about among the hydroids.

As a result of our survey we conclude that the barnacles and hydroids precede *Teredo* in the invading marine fauna. They therefore indicate the possibility of the invasion of this borer but not the certainty that it has arrived.

There is fortunately another marine animal of cosmopolitan distribution, the European edible mussel, *Mytilus edulis,* whose somewhat angular black shell is attached to rocks, piling and any stable or floating substrate. The young of this mollusk settle down from midsummer to autumn and during that time, and later, serve as a reasonably certain indicator that the conditions at the locality where they occur in the matter of food and salinity are entirely suitable for the attachment and growth of the related mollusk, *Teredo navalis.* The occurrence therefore of young mussels on marine piling is a danger sign for the engineer to look out for *Teredo.*

Teredo navalis, barnacles and mussels made their appearance in the wharf of the Mountain Copper Company at Martinez, in the winter of 1920. Mussels and *Teredo* became fewer in number shoreward, both disappearing 300 feet from shore, by reason of decrease in salinity and presence of tailings. Both were exterminated by the flood waters of April-May, 1920.

RECOMMENDATIONS

There is one outstanding feature of the present outbreak of marine borers in San Francisco Bay and of this survey which affects State and Federal supervision of navigable waters and of shipping and engineering practice in the construction and maintenance of marine structures, such as wharves, moles and piers. It is this, namely, that within the area infested by marine borers all unprotected woodwork is a potential breeding ground for harboring these pests, increasing their numbers, and sending forth either their migrating larvae as in *Teredo navalis* and *T. diegensis,* their millions of ova as in *Xylotrya,* or their straggling young as in *Limnoria* and *Sphaeroma.* In every case an infected bit of wood is a contagion spot. The degree to which this is true was illustrated by the fact that in examining the sewer outlet at Pinole we ran across some short sticks of river driftwood lodged in the rushes between tide levels, bits not over a foot in length and 1½ inches in diameter. Examination proved that even these stray bits of wrack were crowded to the limit with *Teredo navalis.* How much more then is the great Mare Island dike with its thousands of piles shot full of *Teredo,* a source of contagion for every commercial structure in the bay. It is washed every day by the tidal current which mingles with the waters of Suisun Bay and the Golden Gate, as the more than one-third of a cubic mile of water passes in and out of the Gate with each mean tide. A single infected pile in 25 feet of water and its 100 square feet of surface affords shelter for upwards of 150,000 *Teredos* and each of these is capable of producing more than 2,000,000 larvae per year. Each pile, barring the death rate of larvae, thus produces enough young to seed 2,000,000 other piles.

It is good engineering practice for the conservation of investments for each engineer to reduce in his own structure as far as feasible all untreated timber and to encourage the State and Federal authorities by coöperation or legislation, if necessary, to restrict wherever feasible the use of untreated or unprotected timber in harbors and the careless turning loose into our harbors of the flotsam and jetsam of timbers, piling, lumber, boxes, and miscellaneous rubbish which litter the shores of our bay, mar their beauty, and become constant sources of contagion to all new timber exposed in its waters. If the engineering profession, which has a large part in the establishment of the standards of practice in marine work should set about to do this it would soon become so illegal and unethical to continue present practices of an almost entire absence of marine "policing up," as it is now to dump our garbage in the public street. I suggest, therefore, that this body refer to their committee on resolutions for consideration and recommendation the following matters: (1) the policy of restricting uncontrolled use of untreated or unprotected timbers in marine structures, (2) the policy of the removal by State or Federal sanction of old unused infected marine structures, and (3) the policy of the prevention of the use of harbors as a dumping ground for waste wood.

A second recommendation results from the fact that the infection of timbers by borers may be a matter of the attraction of the larvae to the wood by its extractives, and the effectiveness of protective measures rest in part upon the repellant action of certain extractives of creosote or other medium employed. To the end of perfecting means of protection, it is desirable therefore that the chemist, wood preserver, and biologist combine in an investigation to establish by experiment a method of treatment which shall be effectively repellant for as long a period as possible to the larvae of the marine borers.

The third recommendation comes as the result of our observation and experience in dealing with this outbreak of *Teredo* in San Francisco Bay. As we have shown, it is highly probable that the bay is now thoroughly seeded with *Teredo* and that even in normal years there is a possibility of its invading the territory above Carquinez Straits with sufficient effect to cause some damage, and that its potentialities are not as yet tested in the lower bay. Therefore, in this locality, it is desirable as a precautionary measure, that any engineer in charge of marine structures carrying the *Teredo* hazard should take steps to keep himself informed as to the prevalence of *Teredo* and other borers in the neighborhood by a system of untreated test timbers planted at points of greatest exposure for the purpose of determining the settlement of borers throughout the year and the rate of progress of their work. We have accordingly proposed in Appendix C a system of planting of timbers, one each month, whereby the inspector can determine at any time the nature and intensity of the settlement of new borers and the rate of their destructive action for the year past, when once the system is in full operation.

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ENGINEERING PHASE

SURVEY DATA ON PILE PROTECTION MATERIALS, METHODS, AND THEIR EFFECTIVENESS IN SAN FRANCISCO BAY

By G. M. HUNT and C. L. HILL

To the engineer responsible for the design, construction and maintenance of structures in sea water, accurate information on the relative cost and the permanence of various kinds of piling and pile protections is of the greatest importance.

The lack of such information prevents a close estimate of the probable annual cost of structures on piling of different kinds and is bound to result many times in the adoption of uneconomical materials or methods. There is no way to estimate accurately the money value of information of this kind, but when the amount of damage done by marine borers in recent years is considered, or even the annual expenditures in normal years for new construction and repairs, it is obvious that information resulting in but very slight improvement would permit savings of very considerable sums of money. A file of data available to the public giving detailed information on the cost and effectiveness of all the major installations of piles and pile protections in San Francisco Bay during the last ten years would now be worth thousands of dollars, and would be paying big returns on the investment that would have been required to build it up. It is of little value to know the present condition of a group of piling without knowing how long it has been in service.

Your Committee has fully recognized that its main purpose should be to collect data and information of this kind, and without neglecting other features of the survey, which are of peculiar importance in this locality, it has paid special attention to securing engineering data on pile protection. This task has been a difficult one, because in so many cases accurate and authentic records of the materials used, the dates of installation or the subsequent repairs in a structure are not available. In several cases, records which would be of considerable value to the Committee were destroyed in the fire of 1906. The lack of records can sometimes be met in part by information from the engineers who built the structure, but it frequently happens that these engineers cannot now be located. In some cases the information might be obtained by searching through old records. This has been done by the committee members to as great an extent as time and personnel permitted, and valuable data has thus been secured. There still remains a mass of data hidden in the files of various offices which would be available to the committee if time could be taken to dig it out.

In the early part of the study the Committee spent considerable time in securing general information about the conditions existing in various parts of the bay, the types of construction in use, with their advantages and disadvantages, studying the marine borers and their distribution, locating sources of information, and in general, orienting itself for the second phase of the study. This consisted in securing in as great detail as possible information concerning specific installations of piling and pile protections. It required searching through old records for original data, and in many cases following this by inspections to learn the present condition of the piling. These inspections could not always be made in as thorough a manner as desired. The appearance of piling from a boat at low water does not always give its true condition, as serious damage may exist below the water line without being apparent. Whenever possible therefore arrangements were made to have piling pulled. In some cases the results of inspections by divers were obtained.

In the following pages are given descriptions of the important methods of protection which have been used to any extent in this region, and such data as the Committee has been able to secure concerning their cost and effectiveness. At best this data is all too meagre and it is strongly urged that the work of securing additional data be actively continued next year.

DURABILITY OF UNTREATED PILING

The value of any method of protecting piling or of any substitute for wooden piling depends upon the life which can be obtained from the protection in question as compared with that of untreated, unprotected wooden piling. In a region as large as San Francisco Bay and its tributaries, where the water conditions vary from the freshness of river water to ocean salinity, and from the extreme contamination by sewage and factory wastes from great cities to the relative purity of ocean water, it is to be expected that great differences will be found in the durability of untreated piling in various locations. In the biological part of this report, other factors are discussed which influence the distribution of the several borers, and the severity of their attack.

The principal piling timber of San Francisco Bay is Douglas fir (Oregon pine) brought down from Oregon and Washington. It has been used for many years almost to the total exclusion of other species, whose use has been almost entirely experimental. In table 1 is given the most important of the data the Committee has been able to obtain on the durability against marine borer attack of untreated fir piling, together with the available data on full sized piling and experimental sections of other species. Redwood and blue gum (*Eucalyptus globulus*), although frequently asserted to be immune to borer attack, appear but little if any better than other common species.

EXTERNAL PROTECTIONS

The need for protecting piling against marine borers has aroused the interest and the inventive genius not only of those directly concerned with the building and maintenance of piling structures, but of a multitude of others. Numerous devices, materials and methods have been suggested. Some of them have been so impractical that their only value has been to demonstrate the ignorance of their sponsors concerning the requirements of a pile protection and the results of past experiments. Some of them, on the other hand, have considerable merit and extensive experiments with them have been justified.

All the suggested external protections which have come to the Committee's attention may be placed in one or other of the following classifications: bark, metal sheathings, paint and paint combinations, concrete jackets and miscellaneous devices or processes.

Bark

It is known that the bark of fir and hemlock and of many other species is not as rapidly attacked as the wood itself and this has naturally resulted in many attempts to use piling with the bark on. Since bark adheres to the wood more firmly in the winter than in the spring it is common to require that such piles be winter cut. At best, however, the bark is in danger of being knocked off in patches during the hazardous course of the pile from the stump to its place in the structure. Unless all such piles are scrupulously rejected, this exposes the wood in spots and permits immediate attack at those points. Borers working in these patches soon enlarge them by burrowing under the surrounding bark. The softening action of the water, coupled with the abrasive action of drift wood and waves tear off additional bark and soon the pile is in a practically unprotected condition. Furthermore the borers are not entirely repelled by the bark. A few specimens of bark were secured from a pile at the Standard Oil Co. dock at Richmond, during this survey, which show large burrows of shipworms.

In the report of the California Board of State Harbor Commissioners for 1871, at which time it was current practice to use untreated piles with the bark on, it is stated that the ravages of the shipworm necessitated the renewal of the piling at least every three or four years.

Mr. L. J. LeConte, M. Am. Soc. C. E., in 1898, when referring to the problem of protecting piling in San Francisco Bay, is reported to have said, "Some ten years ago the specifications of the Harbor Commission Engineer demanded that all piles furnished should have a perfect coating of natural bark; the trees to be felled in the winter months when the bark is more adherent. Now the teredo pay little or no attention to the bark. The writer has seen several samples which were completely riddled with teredo holes."

A company at Richmond in 1920 reports concerning their past experience, "Where bark is kept intact this class of pile lasts from four to five years in this locality."

In Forest Service experiments made at Fort Mason in San Francisco Bay, and at San Diego, experimental pile sections of unbarked western hemlock showed attack within six months, both by *Limnoria* and shipworms. The attack began in patches where the bark had been broken off in handling. In two years the *Limnoria* attack in one specimen was 1¾ inches deep, and some *Xylotrya* galleries 30 inches long and ⅝ inch in diameter had developed.

It cannot be definitely stated that bark covered piles have never given good results, but the evidence which has come to the attention of the Committee indicates that the additional life to be expected by leaving the bark on is uncertain and not over one or two years.

Metal Sheathing

Sheathing piling with copper, yellow metal and other metals has been tried in various parts of the world for many years. An ancient practice to attain a similar metallic protection was to drive large headed nails into the pile so thickly that the surface was entirely covered. Considerable has been written on the results which have been obtained with these protections throughout the world, but the committee has not been able to review this literature for presentation in this report.

which was brush-coated while clean and dry with hot asphalt, grade coupled with the abrasive action of drift wood and

In San Francisco Bay copper sheathing has been used in several instances. One company reports that copper sheathed piles were driven in its wharf at Richmond in 1903 and 1904, as follows:

> "These piles were green, well stripped, all knots and projections cut off and finished to a smooth surface. From a point, when driven, about two feet below mud line to a point above high water, a heavy saturated felt was applied and nailed on. In turn this was covered with 16 ounce sheet copper closely nailed with copper nails. The work was neatly done and had a very nice appearance, was at that time a little more expensive than creosote and no doubt was an excellent protection against the teredo. It has its disadvantages in the following ways: the copper being of light material, striking and floating objects would tear it, bay pirates would cut it off, and changes in depth of water due to wharf construction changing tide rips would remove silt below copper covering and allow teredo to enter."

Six hundred and eighty two of these piles were driven. About 440 of them had a concrete jacket placed around them in 1908, because the mud had washed away from the bottom, exposing wood below the copper. At present, about 105 of the original copper sheathed piles are still in service without having had additional protection, and they appear to be in good condition.

The Northwestern Pacific Railroad has used piles sheathed with copper and with yellow metal under its docks at Tiburon and Sausalito. Some of these were used as early as 1884. The detailed records concerning these piles are not available, but it is reported that in the main, they gave long life. Some trouble due to the metal being torn by drift or by thieves is reported, but there was no trouble from scour.

As long as the copper remains intact the pile is secure from the borers and the above records show that on many of the piles installed 15 to 20 years ago, the copper is still giving protection. The apparent disadvantages are the danger of damage in handling and driving, and from driftwood and thieves after the piling is in place, and the danger from mud scour exposing unprotected wood. While the cost of copper sheathing per lineal foot is high, it is only necessary to cover the pile from a point a few feet below mud line to a point above high water.

Paint and Combinations of Paint with Other Materials

The use of various paints, or applications painted on, to preserve wooden piling, while among the earliest means to be tried, is also one of the most persistent. Tar and asphalt have been the most often used, but they are shown by experience to be of little if any value, so applied, at least without special treatment. At the Mare Island Navy Yard an experimental pile which had never been in salt water, and which was brush-coated while clean and dry with hot asphalt, grade

D, on July 14, 1920, was pulled on October 18 following, and found to be heavily attacked by *Teredo* to a depth of as much as two inches. It was plainly apparent that the teredos had almost everywhere gone through the asphalt coating, and not alone through abrasions or other accidental openings in it. On another pile, where the action of the asphalt itself could be better observed by reason of the pile being wrapped with burlap saturated with the asphalt, the latter was found to have emulsified during the three months, in the outer four out of twelve layers.

A considerable number of hydrocarbon compounds intended for brush application are now being actively promoted, in which the hydrocarbon base has been so treated chemically that it remains viscous and elastic almost indefinitely, and to it have been added various poisonous constituents to kill any animal or vegetable growth which attempts to penetrate them. None of these preparations has been given any real experimental trial in San Francisco Bay, although in experiments elsewhere some of them are said to have resisted shipworms over periods during which untreated wood beside them was destroyed. All these promoters of surface applications, without additional mechanical reinforcement or protection, forget, however, the battering of vessels, or of driftwood under storm action, to the hazard of which a pile in service is subjected, as well as to the boring animals. As soon as any portion of the paint protection is thus removed a door is thrown wide open to the borers.

A great variety of protections have been suggested and tried in San Francisco Bay, which consist of some kind of heavy paint of a bituminous, asphaltic or similar nature, combined with burlap, felt, roofing paper, wire mesh, wood battens or other material. The object of these combined materials is to strengthen the paint coat, and make it less subject to being broken or torn off. The protections of this class differ among themselves as to the nature of the paint used and the materials and methods used in applying the reinforcement. The details and methods of applying any one of them have also varied somewhat from time to time as market conditions, opinions of engineers and the experience gained in placing the protection, driving the piles and observing their behavior have indicated that changes were desirable. They are all similar in principle, however, and possess similar advantages and disadvantages.

The Committee understands that this general method of protection is not patented. This understanding is based in part upon the following statement which was made a number of years ago by one of the interested companies. "The materials used by us are not patented, nor is the method, although both materials and methods were patented. The patent on the materials has expired, while that on the method was declared invalid, hence materials and method are open to the world.'' From this it would appear that aside from the patents which may exist on certain prepared paints which may be used, this method of protection is available for the use of anyone. The Committee has not attempted to investigate the patent situation, however, and does not pretend to speak with authority on this subject.

The Keywest Armor process is reported to have been used but once, which was in this bay in 1889 on piles for the Fremont Street wharf, San Francisco. The process consisted of painting the pile with bituminous matter, wrapping with 9 oz. canvas, and fastening the canvas on with nails 4 inches apart, applying a coat of bituminous compound and finally coating with coral sand. The results were not satisfactory, the protection lasting only about three months.

The Perfection pile, sponsored by a Mr. H. L. Rood, was installed in several locations on the San Francisco waterfront in 1894. The process consisted in mounting the pile in a huge lathe and wrapping it spirally with burlap, which was wound on to the revolving pile from a cauldron of hot tar or asphalt in which it had soaked. To hold the burlap in place a heavy wire was then wound around the pile in a reverse spiral. The wire soon cut through the burlap, however, which fell away and left the pile exposed to borer attack. The process was finally abandoned.

The ''Paraffine Paint Method'' has been in use to some extent since 1889. In 1892, 1151 piles for the Powell Street pier, San Francisco, were coated by this process, and there have been numerous installations since that time. The details of the treatment of the Powell Street piles are not given, but in 1911 the following specifications covering their process were furnished to the U. S. Forest Service by the Paraffine Paint Company:

> ''The piles having been delivered in some convenient place for coating will first be barked the distance they are to be protected and all knots and projections on the above mentioned part of the pile removed.
>
> ''The barked portion of the pile will then be given a heavy coat of P. & B. Pile Paint, care being taken to fill all checks and to cover all surfaces thoroughly. P. & B. Pile Covering will then be closely fitted around the pile, and all laps well cemented with P. & B. Paint and nailed with 1¼ in. galvanized nails, not more than 1½ in. between nail centers. Where necessary a double row of nails will be driven. This pile covering will then be given a heavy coat of P. & B. Asphalt, into which will be imbedded a close fitting lagging of redwood battens, 2 in. by 7⁄16 in., nailed on alternate edges with six penny galvanized wire nails, not more than 9 in. between nail centers, ends of battens to be double nailed. This lagging is then to be given a heavy coat of P. & B. Asphalt, care being taken to fill all spaces between the battens and to give the finished surface as smooth an appearance as possible.
>
> ''As above finished the pile will be ready for removal and driving.''

Concerning the "Pile Covering" the following information was given:

> "The material used by us is a heavy jute burlap, weighing either 10 or 15 oz. to the yard, 33 in. wide, according to the engineers specifications—the heavier weight being that preferably used. This is saturated and coated with a specially prepared asphalt and backed with saturated felt. The heavy grade pile covering weighs about 60 pounds to the 100 square feet, while the lighter weighs about 45 pounds to the 100 square feet."

The exact nature and composition of the paint and the asphalt are, quite naturally, not given. The asphalt is understood to be applied to the burlap cold.

During 1920, 80 piles were covered by the Paraffine Paint method by the Northwestern Pacific Railroad for use in the renewal of trestle approaches to the drawbridge over Petaluma Creek at Black Point. The length of these piles ranged from 75 to 107 feet and they were covered for an average distance of 32 feet, being the distance from a point above high water line to 10 feet below the mud line when driven. The bark was first removed from the portion of the pile to be covered, then a coat of P. & B. pile paint was applied. Over this, P. & B. pile covering was placed and over the pile covering a hot coat of "Floatine" (an asphalt base paint), then ½ in. × 2 in. redwood battens and finally another hot coat of "Floatine." (Pl. 4, fig. 1). The protection was applied by the Northwestern Pacific Company at a cost of 62 cents per lineal foot of pile covered. There was an additional cost of $5.93 per pile for taking the piles out of the water for treatment and rolling them back afterwards.

This work is in progress during the preparation of this report. A total of 252 piles ranging from 70 feet to 107 feet in length will be covered for an average length of 32 feet on each pile.

The Chief Engineer of the Northwestern Pacific states that this method of protection was adopted for this structure for the following reasons: The estimated cost per pile was materially less than the estimated cost of creosoted piles; the old trestle of untreated piles had been in place at this point for 33 years and so far as ascertainable the marine borers had not molested it prior to the last two years, and it was believed that with the return of a normal winter rainfall, the salinity of the water in the stream would be sufficiently reduced to exterminate borers. It was believed that it was reasonable to assume that conditions existing for 31 years prior to the last two years, would be restored before the temporary protection afforded by this method of treatment had deteriorated to such an extent as to permit damage by the borers. From experience with piles protected in the same manner and driven under wharves at Tiburon by the same company about twelve years before, it was believed that this treatment could be counted upon to protect the piles for from five to eight years. There is but little driftwood or wave action in the stream to cause abrasion. Moreover, because of the difficulty of satisfactorily bracing a timber trestle on account of the depth of water and the increasing wheel loads, it was presumed that this structure would be rebuilt with concrete and steel within a period for which the method of treatment adopted might reasonably be expected to furnish protection against the marine borers in the event they should remain in this stream permanently.

This process and the conditions under which it was used have been described at length because they are typical for the better protections of the class to which it belongs.

The Columbia Paint process, as used by the San Francisco-Oakland Terminal Railways in 1913 and 1914 was similar to the Paraffine Paint method, and consisted in applying to the piles a coat of the Harbor Brand Compound, a paint made by the Columbia Paint Co., a coat of burlap soaked in the paint, redwood battens and a final coat of paint.

The Moran process was used in 1913 on 50 piles driven by the San Francisco-Oakland Terminal Railways. These were treated similarly to the above piles except that Moran's Preservative Compound, made by the Moran Paint & Oil Co., was used and the burlap was omitted, a wire mesh embedded in a heavy coat of the compound being used to hold the coating. Battens were soon added, however, on account of the rubbing of the piles when rafted. The battens themselves were then protected with a final coating.

The Argentine Quebracho process. In 1920 the San Francisco-Oakland Terminal Railways coated 160 piles with about 20 feet of protection consisting of a coat of "Argentine Quebracho Commercial Paint," a layer of ½ in. by 2 in. redwood battens and a coat of paint over the battens. The second coat of paint was sanded to harden the surface and prevent the piles from sticking together in the rafts. The same process is also being used by the 6-Minute Ferry Co. at its slip at Crockett.

These examples of protections of this kind might be added to by describing other installations, but this seems unnecessary.

Cost and value of paint protections. The cost of these protections is less than that of practically all other methods of pile protection which have received serious consideration. The Paraffine Paint piles in 1892 are reported to have cost 36 cents per lineal foot for the treatment. In 1913 the same price is reported. From another source the information is obtained that, about 1911 labor cost was about 9 cents per lineal foot, material 20 to 24 cents per lineal foot and about 5 cents was added for the contractor's profit.

The chief advantages of paint and batten coatings are their relative cheapness, ease of application and the possibility of limiting the protection to the part of the pile exposed to the borers. It has been common practice to apply the coating so that it will extend from two or three feet below the mud line to a point above high water. The proportion of a pile which must be coated will therefore depend on the length of piling required to get a good bearing, and the depth of the water. In soft bottom in shallow water it may be necessary to protect but a short portion of the pile. The cost per pile may therefore be quite low.

Perhaps the main disadvantage of protections of this kind is the ease with which the surface coat of paint may be destroyed and the battens exposed. Rubbing together in the raft, careless handling and other mishaps during driving, or battering by driftwood during storms after the piles are in place may very easily scale off patches of paint, or even portions of the battens themselves and the materials beneath them. Barnacles and mussels, developing in crevices and raising the covering may be a contributing factor. When the battens are thus uncovered, borers attack in the bared spots, enlarging the area, destroying the battens and exposing the material beneath. Experience seems to show that without the protection of the battens the burlap and paint coating underneath is soon destroyed. Wire mesh quickly fails from corrosion when its bituminous covering is damaged. It is highly important therefore that piles protected by such coatings be handled and driven in such a manner as to cause the least possible damage to the surface. No precautions however can relieve such piling from the danger of storm battering. It has also been found that in many cases failure was due to the exposure of unprotected wood as a result of the rotting and disintegration of the burlap. This apparently is likely to happen much less quickly when the paint or other compound is applied to the burlap cold than when it is applied hot. In the latter case there is danger of the burlap being burned, and its rotting or disintegration is hastened by the degree to which its fibres are thus injured. When hot asphaltic or bituminous compounds are applied to wet piling, as they often have been in some of these processes, no sufficient adhesion is secured and they are in danger of peeling off as soon as the surface is broken (pl. 4, fig. 2).

A further factor affecting the value of these coatings, which is common to all external coatings applied to only a part of the pile, is the danger of unprotected wood being exposed to borer attack at the bottom. This may happen either by a miscalculation of the necessary length of driving, and therefore of protection, or by changing currents subsequently scouring the bottom away to a point below the protection. The latter may easily occur without being observed and the untreated wood thus exposed be damaged to a dangerous extent without warning.

The records of the thirty years or more during which piling protected with paint and batten coatings has been used in this region should give considerable information as to their effectiveness. Accurate data is lacking, however, on most of the installations. The records which the Committee has been able to obtain are given in table 2. It will be noted in this table that the 50 Moran piles were reported as in practically perfect condition after five years' service. It is to be regretted that these piles were pulled before their useful life was ended, since it is not now possible to compare them with the piles coated by the other processes.

If piling is properly treated by these processes and is not damaged by careless handling, and if its use is limited to locations protected against serious storm action, a life ranging from five to eight years may be obtained. Otherwise such a life cannot be expected.

CONCRETE PROTECTIONS FOR WOODEN PILES

Protections Cast in Place

There are several different methods which are quite distinct from each other.

The stationary form type. Placing stationary forms around piling exposed at low tide and filling the forms with concrete has been tried many times, usually as a protection for piling in place which is being attacked. The details of the forms, reinforcement and methods vary considerably.

The culvert pipe method has been used at one place on San Francisco Bay and is reported to have been used recently at two places on the Oregon coast. It consists of slipping a corrugated iron culvert pipe over the end of the pile, forcing the former as deeply as practicable into the sand or mud and filling the space between the pipe and the pile with concrete. This method has not been used recently in this region, and the Committee has not learned just how the work was done on the Oregon coast. The effectiveness of the method will depend upon the life of the iron pipe, the quality of the concrete and the success in getting the protection deep enough into the bottom to avoid danger from a changing mud line. No data is yet available on the cost of this process, or the durability of the pipe and concrete.

Other cylinder forms, as well as ordinary box forms, have been used in this type of process. The reinforcement, if used, may be in the form of rods, wire mesh or spikes driven into the pile, or it is sometimes omitted altogether. On account of the relative shortness of the protection and the fact that the mud is exposed at low water and the workmen can see their work, it should be possible to obtain good concrete. The necessity of working between tides, however, requires considerable speed, with the accompanying danger of sacrificing quality. Since the protection is exposed at low tide, it is an easy matter to inspect it and to keep it in good repair. This method is entirely feasible where the mud is exposed at low tide, but in deep water it is not practicable because the forms are not watertight and concrete cannot be successfully formed by dropping it through water.

The specific installations of which the Committee has record are as follows:

The city of Alameda in 1914 built a pipe line trestle about 1400 feet long, on 91 two-pile bents spaced 15 feet apart. The piling was green Douglas fir, protected at first by a coating of asphaltic tar, burlap and redwood battens. *Limnoria* attacks soon began, so metal forms were placed at low tide, filled with concrete and later removed when the concrete had set. The cost of this work is reported to have been $4,000, with labor at $2.50 per day. This amounts to an average cost of about $22 per pile.

In December, 1920, the piles were examined at a time when about half of them were exposed down to the mud. On eight of the piles the concrete was disintegrating, on four of them exposing untreated wood. Six other piles were found on which the covering had not been placed high enough, and *Limnoria* were working above it.

In March, 1919, the U. S. Naval Training Station repaired 20 damaged piles at Yerba Buena Island, 16 in. in diameter, by placing No. 16 gauge galvanized iron forms 30 in. in diameter around them and filling with concrete. The concrete was reinforced by No. 10 gauge 4 in. wire mesh secured to the wood and held 2 in. from it by No. 40 spikes. The average cost including labor and material was $2.00 per lineal foot. It is too early of course to determine the effectiveness of this installation.

The removable form type. Methods of placing concrete in removable forms around a pile in place have been in use for several years. The one which has been used in the San Francisco Bay district is that employed by Mr. Frank Camp. Circular wooden forms are provided, 3 feet in length and about 20½ inches inside diameter, made of tongued and grooved wooden pipe staves strengthened with bands of angle iron. They are made in two halves and each half is hinged in the center. The lower form is provided with sheet iron fingers extending inward and upward from the bottom, as shown in photograph. When the form is placed around the pile and the edges are locked together by the tapered pin shown in the left hand form in the illustration, the tips of these fingers touch the pile. Over the fingers, canvas is fastened as shown. The other forms are constructed in the same manner as the lower form, but without the finger arrangement (pl. 5, fig. 1).

The process is carried out by first placing the lower form around the pile at a convenient point above high water line, locking the two halves together with the tapered pins and attaching a cable to each side of the form to hold it up. The form is then filled nearly full with pea gravel which is held in place by the tapered fingers and the canvas. The second form is then placed around the pile, securely fastened to the lower form by six bolts, and filled with concrete made up of 1 part cement, 2 of sand and 3 of pea gravel, mixed soft. Both forms are then lowered until the second form is at the former elevation of the lower form. In this way forms are added, filled with concrete and lowered in succession until the bottom is reached. At this point, if necessary, a high pressure water jet is used to allow the bottom form to penetrate several feet into the mud. The form is left on for about two days and then removed. This is done by jerking out the beveled pins which are all fastened to a chain. This allows the form to open, and by pulling on the cables fastened to the lower forms, the two halves can be pulled out.

It appears that the Camp process is an outgrowth of a former process carried out on the same general principles, but with the use of metal forms. The earlier process was used to some extent a number of years ago on piles at Richmond and probably elsewhere, but it is reported to have since been abandoned by its promoters.

On Nov. 6, in the presence of the Committee, Mr. Camp coated two experimental piles by his process. These were full sized piles, but were experimental in that they were merely set in the mud instead of driven, so that they could easily be pulled for examination. One of them was set in water 28 feet deep at low tide and the other in 18 feet of water at low tide, both in strong tidal current. On the long pile, approximately 40 feet of concrete was placed, extending into the mud to a depth of 2.8 feet. This was done in 32 minutes. On the other the concrete was approximately 28 feet long and required 21 minutes to place.

On Nov. 27, in the presence of the Committee, the long pile was pulled for examination (pl. 5, fig. 2). The upper half of the concrete was good except for a large laitance hole about four feet from the top. The lower half of the concrete was not in good condition and in some spots could be kicked to pieces. In other spots there was a thin shell of good concrete on the outside, while on the inside the material was like mud. The whole lower 15 feet of the casing was broken off without difficulty with a sledge hammer. On Wednesday, December 1, the shorter pile was pulled and the concrete was found in excellent condition.

The results of this test can not be considered conclusive, since not enough piles were coated to show what the average results would be. It appears, however, that the process is likely to be more successful on piles in shallow water than on piles in deep water. It seems possible that the mixture tends to separate somewhat, as it slides down the pile, and the greater the distance it has to slide the more is the likelihood of getting a poor mixture. It is also possible that sea water got into the forms to some extent.

About 2600 piles are reported to have been protected during the last few months by this method at the dock of the California Wharf and Warehouse Co. at Port Costa. The length of the protection required was up to 28 feet, averaging about 15 to 18 feet. The cost of this work is reported to be about 50 cents per lineal foot for materials and $1.50 per lineal foot to the contractor to cover labor and other costs and his profit. The company employs an inspector to examine each finished coating very carefully, using a hook on a pole below water line. Defects found above water can be easily repaired. When defects are located below water, larger forms are used and a new jacket is cast over the first one.

The advantages of this process are, (1) the possibility of repairing damaged piles in place, with little or no disturbance to the structure or interruption of business, (2) the possibility of coating piles at any stage of the tide, (3) the rapidity of the work, and (4) the relatively short portion of the pile requiring protection. The latter advantage is common to all the coatings placed over part of the pile only, and is in contrast to the use of creosoted wood or cast concrete piles where a large part of the expensive material is below mud line where protection is not needed. The disadvantages of the process are: (1) the danger of getting defective concrete, especially at the greater depths. (2) The danger of getting the concrete thin on one side and thick on the other. This is especially likely to happen if the pile is leaning or crooked. (3) The disturbance of the mud caused by the water jet or by removing the bottom form. This may leave wood exposed below the concrete. It is a question whether the holes thus formed will tend to fill up with mud, or whether an eddy will form and keep them scoured out. (4) Mud scour. The bottom may scour away leaving wood exposed below the concrete. (5) The need of having the work done by a thoroughly skilled and responsible crew.

This process has not been in use long enough to give data on its effectiveness. The former process, using the metal forms, gave excellent results on some piles and very unsatisfactory results on others at the Richmond docks. Accurate data on the number of piles protected, the percentage of good results and the average life obtained could not be secured.

The Holmes Pile. This is a composite pile, formed by driving around a wooden pile, in place, a water tight form made of wooden staves. The form is driven into the foundation below the line of possible scour. The form has a driving lip or bell at the bottom and between this bottom and the pile is a special gasket to displace the mud and water and prevent their entrance at that point after the form is in place. The mud and water are then pumped out, reinforcing rods are set and the space is filled with concrete. The cylinder extends above the top of the pile, and when the concrete reaches the latter point its pouring is continued up to the bearing level required, so that the wooden pile is completely encased in concrete down to several feet below mud line and becomes the elastic core of a composite whole whose concrete shell and cap are also factors in its load bearing capacity. As used by Mr. Howard C. Holmes, the patentee of the process, the forms were built up of 3-inch wooden staves held in place and tightened by means of round steel hoops. In some other cases 2-inch staves have been used. The diameter of cylinders used for the single-pile protection has generally been 2 feet (pl. 6, fig. 1).

A modification of this type of pile consisted in placing the wooden form, or in some cases a steel one, around three or more piles in a cluster and filling with concrete as before. For this three-pile or cluster protection a cylinder diameter of 3½ feet or 4 feet was used. A gasket was not practicable in the three-pile construction, and after the form was driven into the mud sacks of concrete were thrown in it to seal the bottom.

Pier 34 on the San Francisco waterfront was built in 1910 by Mr. Holmes, on 777 cylinders 2 feet in diameter, each protecting a single untreated pile (pl. 6, fig. 2). Piers 7, 19, 21, 23, 25, 27, 42 and 44, containing a total of 2893 cylinders, were built between the years 1901 and 1906, using three-pile clusters surrounded by concrete cylinders 3 ft. 6 in. and 4 ft. 10 in. in diameter. Pier 34 is still in good condition throughout the pile protection. Of the remaining piers, all the cylinders have been removed from piers 42 and 44, due to faulty construction, and about two-thirds of the cylinders were removed from piers 7, 19, 21, 23, 25 and 27 in the years 1913 and 1914 (pl. 7, fig. 1). Of the original cylinders in these piers about 10 per cent are in good condition. The cluster cylinders under the pier built by Mr. Holmes in 1901 for the Spreckels sugar refinery on the ocean side of San Francisco are said to be all in good service at the present time.

The principal defects which have caused the deterioration and failure of the cylinders removed were: (1) poor concrete due to its flooding during placing; (2) mud and sand pockets due to failure to remove these materials and sufficiently seal the bottom before concreting; (3) arching of the concrete due to difficulty or carelessness in placing or tamping it; (4) laitance pockets and joints due to difficulty or negligence in cleaning surfaces where concreting was interrupted; (5) exposure of unprotected wood at the bottom if the cylinder is not carried low enough to provide against the lowering of mud line due to subsequent dredging or scour. As used by Mr. Holmes, however, the form, and the concrete, are carried not merely below the mud line but to a substantial bearing.

The difficulties of the original method are intensified in the case of the cluster protection, since it is impossible to seal the bottom with a gasket such as is used with a single-pile cylinder, and throwing in sacks of cement is not thoroughly effective unless done with skill and care; the increased size of the form weakens it, unless the thickness of the sides is increased, and thereby increases the probability of leakage through the sides; and proper tamping of the concrete is much more difficult than in the case of the single-pile form. The cluster form is now no longer used by Mr. Holmes.

It is only fair to note that the defects enumerated above can in the great majority of cases be traced directly either to careless or ignorant workmanship, or to an endeavor to reduce the cost of the process. But insofar as the process requires for its success a degree of intelligence and skill which is difficult to obtain, its practical usefulness is lessened. On the other hand, the fact that one complete pier of single-pile cylinders (pier 34) and at least 10 per cent of the more difficult cluster cylinders have given satisfactory service for periods of from 10 to 20 years is evidence that this method can be satisfactorily applied under suitable conditions and with careful methods of construction. With watertight forms, careful cleaning and intelligent placing of properly proportioned concrete the results obtained in pier 34 may reasonably be expected.

Other protections of somewhat this same type have been used. The most important was probably what was known as the Black Patent, which was used a number of years ago, especially in piers at Richmond. The enclosing cylinder was of metal and at the bottom was a diaphragm of overlapping leaves, to exclude water and mud. No reinforcement was used at first, but later Clinton welded mesh was used. The forms were driven only a few feet below the mud line, and the concrete was not carried above the top of the wooden pile, so that it did not function to any extent in the load bearing capacity of the pile. No complete description of this pile or its installations has been secured by the Committee. Its use is no longer being actively promoted.

Precast Concrete Protections

The Koetitz Pile. This pile is formed by slipping over an untreated wooden pile, in place, a precast reinforced concrete cylinder and driving the cylinder into the mud, then filling the space between the wood and the concrete with sand or grout. When the wooden pile is driven at the time the concrete protection is to be applied, if the bottom is soft, blocks are fastened to it at a point which will be several feet below mud line. The concrete cylinder is supposed to rest on these blocks. The concrete being precast on shore can be made of good quality and the quality can be assured by inspection.

Pier 17 at San Francisco was built on 1050 of these piles in 1912. The cylinders used were 26 inches in diameter, outside dimensions, and the walls were 3 inches thick. They were driven about 8 feet into the mud and extend upward to the under side of the steel deck beams. The wooden piles were cut off at about mean sea level and the cylinders above the heads of the piles were filled with concrete, into which the beams were anchored by steel bars. The space between the wood and concrete was filled with sand in the early part of the work, but later a grout filling was used.

No data is available on the cost of this work. The condition of the piles at the present time is excellent. A careful examination from a boat showed no defects above low water. On January 3, 1921, a diver made an examination from low water to the mud line of 50 piles selected at random and covering the entire length and width of the pier. No defects of any kind could be discovered. Between 1907 and 1911 several hundred Koetitz piles were driven in bulkhead wharves along the San Francisco waterfront. Some of them are now showing small defects but the majority are in good condition and all are still in service.

This protection seems well adapted for soft mud bottoms, and might be jetted into hard ground. When it is possible to use them and when the casings are made and placed with sufficient care, good protection can be obtained. Their durability is then affected by the factors which ordinarily influence the life of good concrete in sea water. There is some danger of developing cracks during handling, which would admit sea water to the reinforcement and permit rust to form, but this can be prevented by care in the handling. The cost is relatively high and a long life would therefore be necessary to justify it.

MISCELLANEOUS PROTECTIVE DEVICES

Several methods have been proposed for pile protection which can not be classified under any of the above heads. The following are examples:

The built-up pile. Much was hoped for this pile at one time. It was a square or rectangular pile built up of separate planks spiked together so as to have, from any direction, the greatest possible number of cracks intercept a path through the pile. This was on the commonly accepted belief that the shipworm would not cross a crack. But whatever the scruples of the shipworm it soon became apparent that *Limnoria* had none. A layer of felt beneath the outside planks helped somewhat; but the spikes in course of a little time loosened and opened the cracks till they offered shelter instead of discouragement to borers. The construction of this type of pile was not continued.

Floats loosely fastened around the pile so that they will rise and fall with the tide and keep constantly in motion from wave action have been actively promoted for some years. They are made in various forms, with or without chain festoons to assist in warding off the borers. No record of their commercial use in San Francisco Bay has been found by the Committee, but they have been installed for a number of years on a pier at Long Beach, Calif. The piles there were attacked by limnoria in scattered spots within a few months. No recent inspection has been made, so far as the Committee has learned. The effectiveness of this scheme is unproved in water where borer action is known to be severe. The minuteness of the crevices necessary to shelter the almost microscopic borer larvae from any impact from such a device, the relatively long time between tidal passages when any given elevation is not effectively covered by such a device, and the fact that the most severe entrance attack of shipworms is at and near the mud line instead of at the surface seem, on the basis of present knowledge, to militate against the probable success of these devices.

Electrolysis of the water around the pile, liberating chlorine, which is supposed to kill the teredos in the pile, was actively promoted some years ago, but no record of any actual test of the scheme has come to the attention of the Committee. It seems entirely unlikely that the method would meet with success, because the tidal currents would carry the chlorine away and prevent the borers being subjected to its effects to any great extent. Constant repetition of the treatment would in any case be required to take care of the hordes of larvae arriving with every tide.

Dynamiting in the water around the piles has been tried as a means of killing the borers. A concussion of this kind in water will only kill animal life in its immediate vicinity. In any case, constant repetition would be as necessary as in the case of electrolysis.

CREOSOTED PILES

Notwithstanding the diverse efforts to evolve a perfect protection for piling, no other method has been presented for the consideration of the Committee which has been shown by service records to give a longer life in relation to cost than does creosote treatment. Creosoted Douglas fir piling has been used for many years in San Francisco Bay. It was in use to some extent as early as 1869. In a report dated July 8, 1871, by T. J. Arnold, Engineer of the California Board of State Harbor Commissioners, reference is made to the use of creosoted piling in San Francisco Bay and elsewhere, and a discussion of the subject is given. Mr. Arnold recommended the use of piles creosoted by the Robins Process which was then in commercial use at San Francisco and consisted of treating the wood (after a preliminary steaming and drying) in a huge closed tank 80 feet long, 14 feet high and 11 feet wide, with vapors of creosote admitted into the tank from a tar still at one side. Since that time marked improvement has been made in the preservative treatment of wood and much more is known respecting its effectiveness as a pile protection.

The oldest creosoted structures upon which the Committee has so far been able to secure service data are those of the Southern Pacific Railway. One of these, the Long Wharf at Oakland, was begun in 1890, and when it was removed in 1918 and 1919 on account of harbor changes some of the piles had been in service for 29 years. This structure was reported on at length before the 1920 convention of this Association and the report may be found in the Proceedings.

The Board of State Harbor Commissioners has used a great deal of creosoted piling along the San Francisco waterfront and its use has been quite extensive for many years throughout the lower bay region where borers have always been active.

Service Records

In spite of this extensive use it is not easy to obtain many accurate service records. Engineers have been too busy, or have failed to appreciate the value of such information, and for the most part have not kept their records in sufficient detail for the use of the Committee. The data of value which the Committee has been able to secure is given in table 3. This table gives records of a considerable number of structures, involving a total of over 35,000 piles. In the 1920 Proceedings of this Association, pages 148 to 178, a detailed description of the piling in the Oakland Long Wharf is given, including data on the character of the treatment, the oil used, oil penetration, surrounding conditions, and the results of a detailed inspection of the piling. The table gives a summary only of this record. For the complete record the reader is referred to the above mentioned report.

Briefly summarized, the data in last year's report and in table 3 of the present report indicate that a long life may be expected in San Francisco Bay from good quality Douglas fir piling well creosoted, properly handled in rafting and driving, and not mistreated in the erection of the superstructure. In view of this data it seems clearly possible for creosoted Douglas fir piling, under conditions such as those existing in San Francisco Bay, to give a life of 25 to 30 years, "*provided* that good timber and a high grade of coal-tar distillate oil are used, that the treatment is efficient *and that care is taken in* *handling and driving the piles,*" as was expressly stipulated by last year's Long Wharf Committee. Poorly treated piling or piling damaged by careless handling can not be expected to last nearly as long. When piling must be obtained from a long distance by sea, with the necessity for repeated rafting, storing and handling, damage is difficult to avoid, even with all reasonable care. This is the situation for most piling consumers on San Francisco Bay, and the average life obtained there with creosoted piling has been considerably less than the above figures. What the average life is, however, can not be definitely stated, since none of the available records are in sufficient detail to permit it and so few of the recorded structures have completed their service.

Damage to Treated Material

Your Committee wishes to emphasize again that in order to secure such satisfactory service, good treatment and good oil are essential and proper handling is of even greater importance. The abuse of creosoted piling which the Committee has almost universally found in its inspections is deplorable. Every opening through the treated area below high water, exposing untreated wood, affords access to borers. Limnoria are quick to take advantage of these openings and soon enlarge them to a dangerous extent. The best treatment and oil are of no avail if the borers are given access to the untreated interior of the pile. It is fully appreciated that occasional damage through the treated area can not be avoided, but there is a great deal of unnecessary damage. Some of the causes of damage noted are pike pole holes, rafting dog holes, peavy holes, bolt holes, axe cuts, dapping piles out of line, cutting off pile heads too close to water line, cracks caused in seasoning or by driving, and abrasion by vessels or by driftwood (pls. 8, 9, and 10). If the average life of creosoted piling on San Francisco Bay has fallen short of that shown by the Oakland Long Wharf, it must in large measure be charged to these abuses and their correction would unquestionably result in a much nearer approach to maximum life.

The Committee is aware that evidence of attack, especially by limnoria, has been found to some extent in the treated part of the wood, in South Atlantic and Gulf ports, and has looked diligently, but without success, for evidence of similar attack in San Francisco Bay. A few cases have been found where limnoria, having hollowed out and enlarged some opening through the creosote, have come in contact with the treated wood from the inside and attacked it slightly. Apparently as long as the treated surface remains intact, the borers do not attack it.

The extent of the damage could be reduced, it is believed, if engineers and their inspectors would fully appreciate the importance

of careful handling and take such steps as may be possible to secure it. It is not to be expected that contractors and their men will suddenly change their methods to comply with the engineers' wishes, but gradual improvement can be effected by continuous and concerted efforts to educate pile handlers in proper methods, and by insistence on the observance of approved methods. Special stress should be laid on restriction of the use of dogs in rafting, and pikes in any handling, to the sections near the ends of piles, which will be well below mud line or above high water when the piles are set and the avoidance of cutting the creosoted shell below the water line in bracing.

Damage to fender and spring line piling by boats can scarcely be avoided, and it is obvious that such piling will not last as long as bearing piles. If the creosote preserves the piling throughout its mechanical life it is sufficient. On the abraded side borer attack will usually be prevented by the repeated chafing of boats. On the other parts of such piles attack can be expected where fastenings cut through the creosote or where the pile is split or broken by shock.

Improvements in the methods of bracing the structure could doubtless be made. The practice of extending braces and fastenings below water should be avoided, since placing the braces above the water not only prevents damage to the pile, but it also keeps the bracing out of the water, and hence out of reach of the borers. Restriction of bracing to the area above water line, however, involves admitted difficulties in securing the necessary bracing strength. A study of this subject with a view to making specific recommendations as to methods of construction should be made by next year's Committee.

Treatment of Douglas Fir Piling

The members of this Association are aware from the papers and discussions of previous meetings that Douglas fir is very refractory to the penetration of preservatives in the heartwood. The sapwood is less refractory. But it is difficult to obtain an absorption in Douglas fir piling of much over 12 to 14 pounds per cu. ft. of treated material. The thickness of the sapwood is the controlling factor in the depth of the penetration that can be secured.

The piles driven in Oakland Long Wharf in 1890 and 1892, totaling about 1000, were air dried for a year before treatment, then treated by the Bethel process, absorbing about 14.2 lbs. per cu. ft. The other 13,000 piles in this structure were treated green from the water, by the boiling process as developed by John D. Isaacs, and received an average absorption of about 10 pounds per cu. ft. Since that time piles have been used in the bay treated by the steaming process, the boiling process and the boiling under vacuum process. All three processes are still used to some extent but the present tendency seems to favor that of boiling under vacuum. The Board of State Harbor

Commissioners requires an absorption of not less than 12 pounds per cubic foot, and this seems to be a commonly accepted standard. They require that the process of boiling under vacuum be used, and that a penetration of not less than ⅞ inch be secured. The Committee has not been able to examine all the specifications in use in this region and compare them. The general requirements of the engineers who buy on specifications appear to be similar but there is no specification covering absorption, penetration, character of oil and details of treatment which is accepted as standard. In fairness to both producer and consumer, your Committee believes it very desirable that an attempt be made to draw up a specification of this kind.

Cost of Creosoted Piling

The following data on the cost of creosoted piling has been carefully collected but of necessity must be given in brief and condensed form. These figures represent the prices prevailing in the late summer and fall of 1920 for Douglas fir piling delivered at points on San Francisco Bay. The average specification called for 8-inch minimum tops and 14-inch minimum butts, up to about 75 feet in length, with 7-inch tops for greater lengths, a minimum penetration of ¾ inch and a treatment of not less than 12 pounds of distillate creosote oil of the Standard Grade of the American Wood-Preservers' Association or its equivalent. Some prices were affected by the requirement of quick delivery.

Range in length	Price per lin. ft. f.a.s. San Francisco Bay
30′ to 40′	$0.87 to $0.95
41′ to 50′	0.90 to 0.95
51′ to 60′	0.92 to 0.97
61′ to 70′	0.92 to 1.00
71′ to 80′	0.98 to 1.08
81′ to 90′	1.00 to 1.08
91′ to 100′	1.02 to 1.10
Over 100′	1.05 to 1.16

The Spliced Creosote-Green Wood Pile

Some creosoted piling has been used in San Francisco Bay, to the small or bottom end of which is spliced an untreated piece somewhat shorter than the length which will be driven below the mud line. This device permits the purchase of much shorter creosoted piling, which is also cheaper per linear foot. It may give satisfactory service, if the splice is sufficiently strong, subject to precautions against the exposure of untreated wood by miscalculation of driving length, or by subsequent scouring of the bottom. Mr. Howard Holmes, of San Francisco, has used a metal sleeve of several feet length over the splice. Whether the spliced pile would be economical would depend upon the relation between splicing cost and the saving in creosoted material.

OTHER MATERIALS THAN WOOD

Three types of supports other than wooden piling have been used in San Francisco Bay, namely, iron piles, reinforced concrete cylinders, and reinforced concrete piles.

Iron Piles

Iron piles have been used in a number of government structures about the bay. The first installation appears to have been at Alcatraz Island, where the Quartermaster's dock was built about 1870 on cast iron piles. These piles were 10 feet to 30 feet long, 12 inches outside diameter and the metal was one inch thick. They were all filled with concrete after driving. The longer piles were driven into the mud and the short piles set on concrete bases. Between that time and 1906 a total of about 1250 cast iron or wrought iron piles have been placed in government structures, and practically all of them are still in service. Some of the piles have been broken off by the shock of vessels, or others causes, at the point where the braces are fastened. These were repaired by placing an iron collar around them at the break. When placed, the cost of the piles was about $1.50 per lineal foot. No information is available as to their present cost, but it would probably be around $3.00 per lineal foot. In table 4 the available information concerning the character, location and service given by these piles is presented. It will be noted that some of them have been in service for 50 years, which is a remarkable record.

The chief advantage possessed by these piles seems to be their great durability. Below water they are reported to be practically as good as new. Above low water they have rusted to some extent in spite of attempts to protect them with paint, but they are still serviceable. The iron bracing has rusted more rapidly and on some of the docks has been renewed several times. Among their disadvantages are: (1) high cost, (2) the need for driving them with extreme care in order that the fittings and bolt holes for the bracing may come right, (3) their tendency to break at bracing points, (4) the relatively short lengths which can be used.

Reinforced Concrete Cylinders

Cast in place reinforced concrete cylinders have been used in the construction of fourteen piers on the San Francisco waterfront. While the details of design vary somewhat in the different structures, the cylinders used in pier 28, constructed in 1912 and 1913, are typical of this type of construction.

Pier 28 is 150 ft. in width and 677 ft. in length. It is supported on 452 reinforced concrete cylinders which are spaced approximately 15 feet apart in both directions. The cylinders are 3½ to 4 ft. in diameter and are supported on bases from 5 ft. to 7 ft. in diameter, which rest on a compact bed of sand, clay and gravel at a depth of from 40 to 70 ft. below low water.

The cylinders and bases were constructed in cylindrical open steel caissons 8 ft. in diameter which were sunk to the required depth by dredging out inside with orange peel buckets and driving with a pile driver as the excavated material was removed. After the caissons were sealed by driving into the hard bottom the water was pumped out and the bottom was excavated by hand to an even bearing. The cylinder forms were built up with 2 in. stave lumber hooped with steel bands, and the reinforcement consisted of ⅞ in. square bars spirally hooped with No. 0 wire.

The concrete in the cylinders was mixed in the proportion of one part of cement to six parts of aggregate. The aggregate consisted of several sizes of sand and crushed rock so as to give a graded mixture. The concrete was poured through a jointed pipe and was tamped and spaded so as to fill the 3 in. spaces between the reinforcing steel and the forms. After the concrete had set not less than 24 hours the caissons were pulled, the wood stave forms being left permanently in place.

The cylinder type of construction has proved satisfactory where the work was properly done. The structure is fire proof and permits of the construction of a fire proof shed which is not feasible in this locality on a timber sub-structure. It is rigid and permanent in character and the maintenance is reduced to a minimum. The most serious disadvantage is the difficulty of securing thoroughly satisfactory work, particularly on the outside surface of the cylinders and at the joints. Unless the mortar is well spaded to the outside so as to afford the necessary protection for the reinforcing steel there is pitting of the surface particularly between tides. In pouring the cylinders the work is carried up to the underside of the deck structure in one operation and completed after the placing of the deck forms. In pouring these long cylinders laitance is apt to collect at the top and unless this is removed down to solid concrete before the next section is poured a plane of weakness results. A considerable number of cylinders have been repaired due to these defects but the fact that large numbers constructed from five to twelve years ago are in first class condition proves that satisfactory construction of this type is entirely feasible.

Reinforced Concrete Piles

Reinforced concrete piles, precast on land and seasoned before driving, have been used in this and other harbors for a number of years, where great permanence is desired and high first cost is therefore permissible.

Along the San Francisco waterfront more than 11,000 concrete piles have been used in the construction of five piers as well as numerous wharves, ferry slips and building foundations.

Square piles have been used exclusively on the work in San Francisco, the size varying from 16 in. square for piles up to 45 ft. in length to 20 in. square for piles up to 105 feet in length. At the point the piles taper on two sides for a distance of 6 to 10 ft. to a width of 10 in.

The reinforcement consists of square corrugated bars rolled from billets with spiral wrapping of No. 3 wire. The quantity of reinforcing steel varies, depending upon the length of the piles, from four ¾ in. bars to six 1 in. bars.

In constructing concrete piles, the established practice is to use a mixture of one part of cement to five parts of aggregate. The different sizes of aggregate, usually four, are brought on the ground separately and are proportioned so as to obtain as dense a mixture as possible. Thorough mixing and tamping are required and the mortar is spaded against the forms, which are set so as to give a 2 in. covering of concrete over the steel. All piles are cured at least 45 days before being driven. The driving is done with a heavy steam hammer and with the use of a water jet where necessary.

The first precast reinforced concrete piles were used in 1911 in the supports for aprons of passenger ferry slips. In 1912 a section of bulkhead wharf adjacent to pier 17 was constructed, using concrete piles. The first pier in which concrete piles were used exclusively was pier 35 which was constructed in 1914 and 1915; other structures in which this type of construction was used date from 1912 to 1920.

Based on prices for labor and materials current in the first half of 1920 the cost of reinforced concrete piles is approximately as follows:

16 in. square	$1.50 to $1.70 per lin. ft.
18 in. square	2.00 to 2.20 per lin. ft.
20 in. square	2.50 to 2.75 per lin. ft.

Variation in cost depends upon the length, the weight of the reinforcing steel and the number of piles constructed.

Up to this time the results obtained from the use of reinforced concrete piles on the San Francisco waterfront have been entirely satisfactory. The only defects which have been discovered in the oldest structures are a few vertical cracks in the concrete on the line of the longitudinal reinforcement near the heads of the piles. A critical inspection fails to reveal any instances of deterioration below extreme high tide.

Some of the advantages possessed by this type of construction are the rigid, substantial substructure which results and the possibility of the use of a permanent, fire-proof superstructure. The certainty of securing more careful inspection and workmanship of precast piles built on land makes them more satisfactory than cast-in-place concrete cylinders. The objections to this type of construction are the high first cost and the length of time required for construction of the pile; the high cost of placing and driving the pile and danger of damaging it in that process; and the uncertainty of the length of life which can be secured, on account of the short time during which they have been in service in this vicinity.

GENERAL CONSIDERATIONS

In presenting the information which it has collected on the effectiveness of pile protections, the Committee does not recommend any type of pile or method of protection as the best for every purpose. Each type has its advantages and its disadvantages, making it suitable for some places and unsuitable for others. The importance of the structure, the cost permissible, the permanence desired, and the size, ease of making repairs, etc., all will affect the decision.

Comparative Annual Costs

The Committee is indebted to Mr. Jerome Newman, formerly Chief Engineer of the Board of State Harbor Commissioners, for the following estimates on the annual cost of six different types of waterfront construction. The comparison is based on pre-war contract prices. It is believed that the changes in labor and material costs of the past few years have been fairly uniform for the several types of construction considered, and that the pre-war contract prices will show the relations more satisfactorily for future use than will the erratic fluctuations of those which have obtained during and since the war.

It has before been stated that the Committee found the available records insufficient to establish a trustworthy average life for most of the types of piling construction. The assumptions which Mr. Newman has made in his calculations are of course subject to modification, as the facts in specific cases may require. But his presentation is believed to constitute a sound method of attack upon the problem. Using the assumptions which he believes necessary or legitimate, any other engineer, if Mr. Newman's method is generally adopted, can arrive at results which, in addition to being trustworthily derived, will have the considerable advantage of being comparable with all the others similarly derived.

A life of twenty-five years is assumed for creosoted Douglas fir piling, based upon the showing of the Southern Pacific Long Wharf. It is assumed that in the case of each construction type the cost of construction is financed by the sale of bonds bearing 5 per cent interest and maturing at the end of the assumed life of the pier; that a sinking fund is established at the same rate of interest to retire the bonds at maturity; and that a depreciation or replacement reserve is laid aside at the same rate of interest for the purpose of reconstruction and returning loss of revenue during the time of reconstruction. The distance from the top of the piling or cylinder to the water surface is taken at 5 feet, the depth of water at 35 feet, and the penetration of the piling at 35 feet. The construction costs are per square foot of deck surface.

Based on a twenty-five year life for creosoted piles, the figures show the annual cost of all types for the same length of life. In addition to this the life of all other types has been calculated from an annual cost corresponding to the annual cost of a creosoted piling pier.

ANNUAL COST, 25 YEAR LIFE

Type A—Creosoted piles, first cost $1.00 per square foot.

Interest on investment, at 5%	$0.0500
Maintenance, at 5%	0.0500
Insurance	0.0066
Sinking fund payment	0.0209
Depreciation reserve	0.0230
Loss of revenue	0.0063
Total annual cost per square foot	$0.1568

Type B—Reinforced concrete piles, first cost $2.00 per square foot.

Interest on investment, at 5%	$0.1000
Maintenance at 1%	0.0200
Insurance	....
Sinking fund payment	0.0419
Depreciation reserve	0.0503
Loss of revenue	0.0063
Total annual cost per square foot	$0.2185

Type C—Reinforced concrete cylinders, first cost $3.00 per square foot.

Interest on investment, at 5%	$0.1500
Maintenance, at 1%	0.0300
Insurance	....
Sinking fund payment	0.0628
Depreciation reserve	0.0757
Loss of revenue	0.0063
Total annual cost per square foot	$0.3248

Type D—Untreated piles encased in reinforced concrete deposited inside a wooden cylinder, first cost $1.85 per square foot:

Interest on investment, at 5%	$0.0925
Maintenance, at 1%	0.0185
Insurance	....
Sinking fund payment	0.0387
Depreciation reserve	0.0445
Loss of revenue	0.0063
Total annual cost per square foot	$0.2005

Type E—Untreated piles surrounded by precast reinforced shells driven into the bottom, first cost $2.25 per square foot.

Interest on investment, at 5%	$0.1125
Maintenance, at 1%	0.0225
Insurance	....
Sinking fund payment	0.0471
Depreciation reserve	0.0542
Loss of revenue	0.0063
Total annual cost per square foot	$0.2426

Type F—Untreated piles encased in plain concrete poured above water and lowered into place, first cost $1.40 per square foot. (Derived from the cost of a creosoted pile pier by deducting the difference in cost of creosoted and untreated piles and adding the cost of the concrete protection, assumed at 60 per cent of the present price.)

Interest on investment, at 5%	$0.0700
Maintenance, at 3%	0.0420
Insurance	....
Sinking fund payment	0.0293
Depreciation reserve	0.3373
Loss of revenue	0.0063
Total annual cost per square foot	$0.1813

Life of Different Types for Equal Annual Cost

Annual cost of Type A, $0.1568 per square foot.
Life assumed for Type A, 25 years.

Type B—Maintenance and interest	$0.1200
Annual payments, reserve funds	0.0368
Required at end of life:	
Sinking fund	2.0000
Depreciation reserve	2.4000
Loss of revenue	0.3000
Total required	$4.7000

Life necessary to produce this sum at 5%, 41.0 years.

Type C—Maintenance and interest	$0.1800

As maintenance and interest alone for this type are greater than the total cost of type A, it is at all times more expensive than the latter and its cost increases with its life.

Type D—Maintenance and interest	$0.1110
Annual payments, reserve funds	0.0458
Required at end of life:	
Sinking fund	1.8500
Depreciation reserve	2.1275
Loss of revenue	0.3000
Total required	$4.2775

Life necessary to produce this sum at 5%, 35.6 years.

Type E—Maintenance and interest	$0.1350
Annual payments, reserve funds	0.0218
Required at end of life:	
Sinking Fund	2.2500
Depreciation reserve	2.5825
Loss of revenue	0.3000
Total required	$5.1375
Life necessary to produce this sum at 5%, 50.4 years.	

Type F—Maintenance and interest	$0.1120
Annual payments, reserve funds	0.0448
Required at end of life:	
Sinking fund	1.4000
Depreciation reserve	1.6100
Loss of revenue	0.3000
Total required	$3.3100
Life necessary to produce this sum at 5%, 31.5 years.	

In the above calculations allowance was made for the cost of removal by increasing the depreciation funds as follows:

10% of the first cost for Type A.
20% of the first cost for Types B and C.
15% of the first cost for Types D, E and F.

Revenue for square foot was assumed at $0.3000 per annum and one year was allowed for reconstruction, an assumption favorable to concrete structures.

Maintenance charges were taken at 5 per cent for Type A, 1 per cent for Types B, C, D and E, and 3 per cent for Type F. The parts most subject to wear are fender lines and deck pavements, and as the maintenance cost for these parts is the same for all types, the maintenance percentages assumed are also favorable to concrete structures.

The calculations presuppose the use of the best construction methods with resulting structures not subject to failure on account of the lack of precautions on the part of the builders.

Obsolescence

The question of obsolescence is one of considerable importance. Continual improvements in ships, methods of handling cargoes and changes in the character and volume of commerce require harbor changes to meet them. Some harbors can advantageously build quays, with permanent solid concrete or masonry walls. Ships can berth alongside the quay walls and the warehouses and cargo handling equipment can be placed on a fill behind the wall. This is expensive construction and changes are costly. It is permanent, however, and where conditions permit the expense is justified. The waterfront of the upper bays and Carquinez Straits is largely of this type.

The San Francisco City Waterfront, however, is not of this type, but is a pier harbor, requiring for its most efficient use that vessels be berthed at piers extending into the harbor at an angle with the shore line. This necessitates changes in the piers to meet the changing conditions of ships and commerce. The following extract from a report made in 1919 by Mr. Newman is of interest in this connection.

> "As evidence of the rapidity of the changes that have taken place in ocean transportation in the last few years and the consequent need for new types and larger dimensions for piers, the experience of San Francisco may be adduced. Prior to 1909, the standard pier was 80 feet wide and 600 feet long; it became necessary, on account of deterioration, to replace some of the older structures and it was decided to build for future increase of traffic and to erect permanent piers of sufficient size to handle it. The new piers were 130 feet to 140 feet wide and 650 feet to 700 feet long with 200 foot to 220 foot slip spaces as against 150 foot to 200 foot slip spaces previously deemed ample. In 1912, before commencing the construction of four new concrete piers, a large number of shipping men were consulted and in accordance with their views the piers were made 200 feet wide and 800 feet long with 250 foot slips. Two or three months ago plans were prepared for a new improvement at the southerly end of the water front involving several piers 235 feet in width by 1000 feet in length with 300 foot slips. In other words, in ten years the demands of commerce have increased pier width by about 80 per cent, pier length by 50 per cent, and slip width by 50 per cent; the structures thought ample at the beginning of this ten year period have become inadequate but must remain in service because they are too expensive to be torn down and the new idea of size required can not be adjusted to existing piers."

In another part of his report appears the following paragraph.

> "The life of any structure is of prime importance in forming a conclusion as to the type to be adopted and the expenditure that will be justified. It is not economical to build expensive permanent structures when cheap temporary ones will serve the same purpose, nor on the other hand is it wise to build cheap temporary ones with their usual high maintenance cost when only a permanent one will answer requirements. This is true in all cases, but particularly so in the case of harbor works and the two phases of the subject, viz: physical life and economic life should be thoroughly studied before plans are made. The physical life may be foretold with substantial accuracy if the type of construction has been used long enough to furnish sufficient reliable data, but a prophecy as to the economic life is more difficult, involving as it does the prediction of future developments in the light of past events."

These statements by Mr. Newman show very clearly why the Committee can not recommend any type of piling or pile protection as best. The decision must be made by the engineer for each structure individually. The Committee has endeavored however to present data which will be of value to the engineer in arriving at his decision, and hopes that the work can be continued next year to gather additional data.

SUMMARY

In concluding this part of the report your Committee wishes to emphasize the following points which have been touched upon:

(1) Marine borers are very active in San Francisco Bay, and in places where their attack is severe will destroy untreated piling in as short a time as six to eight months. In other places the untreated piling may last two to four years.

(2) The information secured indicates that it is reasonable to expect a life of five to eight years from paint and batten protections if the work is well done. If it is not well done or if the covering is damaged by careless handling this range of life cannot be expected.

(3) When carefully handled so that there is no injury extending through the shell of treated wood within the water section, it appears possible for properly creosoted Douglas fir bearing piling to give a life of 25 to 30 years in San Francisco Bay. Poorly treated piling or piling damaged by careless handling cannot be expected to last nearly as long. Under existing conditions, with the necessity of using piling shipped in from distant points, and on account of the damage liable to occur during repeated handling, storage and rafting, the average length of life secured has been considerably less.

(4) Most of the attack on creosoted piling by marine borers, which the Committee has observed throughout this survey, appears to have begun in spots where untreated wood has been exposed by damage in handling the piles or placing the superstructure. It is urgently recommended that improvements be made in the methods of handling creosoted piles and building structures upon them, so that damage to the surface of the piles may be reduced to a minimum.

(5) Precast reinforced concrete piles and pile casings have not been in use in San Francisco Bay a sufficient length of time to determine their ultimate life. A detailed examination of those structures which have been in service for 10 years shows no evidence of deterioration and they seem capable of a long further life. The length of life to be expected from this type of construction is largely dependent upon the quality of materials and workmanship and the skill and care with which they are employed; and any laxity in these particulars will materially shorten the length of service which may be secured.

(6) Cast in place concrete pile jackets and cylinders may be expected to give satisfactory results if properly constructed of suitable materials. The difficulties of this type of construction, however, are of such a nature that the probability of securing a maximum length of life is less than in the case of precast concrete piles or pile coverings.

(7) The selection of a type of piling or pile protection for a given structure must be made upon the basis of cost and permanence of the materials under consideration, the character of the structure and the probable need for future alterations to meet the changing requirements of commerce. When a comparatively short increase over the life of green wooden piling is sufficient, the surface protections will often be found economical in waters not exposed to severe storm action; if a moderately long physical life approximating the average economic life of marine structures in this harbor is desired, a good creosote treatment will provide it at the lowest annual cost so far as present knowledge goes; if conditions warrant building for the greatest permanence, with less regard for first cost, concrete construction may be useful. For the protection from further damage of wooden piles already in place and showing attack by borers, not yet severe enough to require condemnation, the concrete casing, precast or poured in place, is the only means of salvage so far found by the Committee.

RECOMMENDATIONS FOR FURTHER WORK

As has been pointed out repeatedly in the preceding pages, this report is intended only as a progress report of the work of the Committee to date and in no sense does it presume to be final or complete. The work which the Committee has been able to do since its organization and the information it has collected serve to emphasize the lack of conclusive data on marine borers and on pile protection, and the great need for continued study of these subjects. The value of such continued study in San Francisco Bay will be three-fold. It will serve to concentrate the attention of local engineers on a problem of mutual interest, and provide a means of collecting and disseminating information of immediate use to them. It will also be of value to engineers throughout the country because a great deal of the information secured is of general application. The study further will serve to draw the attention of the country to a serious national problem, and to create an interest which can not but result in progress towards its solution. In view of these considerations the Committee strongly recommends that the study of pile protection in San Francisco Bay be continued, and makes the following suggestions for the consideration of the new Committee.

1. Continue to collect data in as great detail as possible concerning the service given by piling and protections of all kinds. It is believed that much valuable data of this kind can still be secured with regard to structures in San Francisco Bay. The collection of this data can be greatly facilitated if coöperators will each assign the time of a competent man to bring together the past records of their piling and put them in form to be used by the Committee.

2. Arrange so far as possible for the maintenance of adequate permanent records of piling and pile protections recently installed, and for receiving annual reports on their condition. In a few years these records will become of great value.

3. Give consideration to every new method of pile protection which may be suggested, and report as to its probable merits. When conditions warrant, experiments should be arranged with these methods, on a sufficient scale to give the information desired.

4. Continue the study of the borers themselves with the object of increasing the knowledge of their distribution, habits, life processes and of the biological factors which affect their activities. (See conclusions at end of the biological section of this report.)

5. Study the causes of damage to the treated portion of creosoted piles with a view to recommending definite specifications embodying improved methods of handling piling and improved structural design, especially with respect to bracing, with a view to their acceptance as standard practice.

6. Undertake, in coöperation with all interested parties, the preparation of a standard specification covering the selection, treatment and inspection of Douglas fir piling.

For the San Francisco Bay Marine Piling Committee:

(Signed) F. D. MATTOS,
E. M. BLAKE,
DR. C. A. KOFOID,
C. L. HILL,
Sub-committee on Preparation of Report.

APPENDIX A

List of Contributors to the Fund of the San Francisco Bay Marine Piling Committee

Atchison, Topeka and Santa Fe R. R.
Associated Oil Co.
Balfour, Guthrie & Co.
Bethlehem Shipbuilding Corporation.
Board of State Harbor Commissioners.
California and Hawaiian Sugar Refining Co.
Colman, J. M., Co.
Coos Bay Lumber Co.
Hammond Lumber Co.
Martinez, City of
McCormick, Chas. R., & Co.
Moore Shipbuilding Co.
Mountain Copper Co.
Northwestern Pacific R. R.
Pacific Creosoting Co.
San Francisco-Oakland Terminal Rys.
San Francisco-Sacramento R. R.
Shell Company of California.
Southern Pacific Co.
Union Oil Co.
Western Pacific R. R.

APPENDIX B

San Francisco Bay Marine Piling Survey

PRELIMINARY QUESTIONAIRE

(To be answered separately for each structure)

1. Name of company and officer reporting; address; date.

2. Name, if any, of dock or other structure; and ownership if not as under No. 1.

3. Location of structure. Date when first built.

4. Give plan of structure, showing especially its projection from shore.

5. Give profile of structure, showing water depth from shore line to outer end, for mean low and mean high tides.

6. Give for piling under structure: kind (when of wood, also species and whether treated or untreated), number (of each kind), age, condition.

7. Are marine borers attacking piling under this structure? If so, how serious is the attack? If not, are they active anywhere in the immediate vicinity?

8. Have you any data to show the life of untreated wooden piling in this structure or location? How, if any, does that life vary from shore line to outer end of structure?

9. What steps have been taken to protect this piling? Give dates, extent, and cost of repairs or replacements due to borer attack.

10. If piles are creosoted, have you any records of treatment available for study?

11. If there are coverings or other protections aside from creosote, describe them.

12. If piles are entirely of other construction than wood, what are they?

13. Can you give any further detailed information, such as salinity measurements, tidal and current movements, sewage or debris present in surrounding water, experiments which you have conducted, test specimens installed, etc.?

14. If desired, will you help in getting information such as under 13?

15. Can you give assistance in the examination of your structures for this survey?

16. Have any reports been made on this structure? If so, can a copy be furnished for use in the survey? Photographs?

17. Will any piling be removed under your jurisdiction within the next two or three months? Location and probable date of removal?

18. What is your estimate of the total damage, in terms of repairs or replacements, to date?

Please use a separate sheet for each structure, and address reply to

DISTRICT FORESTER,
U. S. Forest Service,
Ferry Building, San Francisco,
California.

Attention C. L. HILL.

APPENDIX C

Instructions for Coöperators in the Marine Borer Survey of San Francisco Bay

I. DETERMINING THE SALINITY OF WATER

OBTAINING WATER SAMPLES

Sampling.—Samples of water should be taken always at the same determined stations. It is suggested that stations not already established at the date of receipt of these instructions be selected in consultation with the Forest Service engineers.* Samples should be taken at least once each week, from both the surface and near the bottom, and at both high and low tide. This will make not less than four samples for each station, at each weekly (or more frequent) period. Care should be taken to take the bottom samples each time at the same distance from the bottom (say 1 foot). This can best be accomplished by driving a nail in the structure from which the sampling is done, at a convenient point to the operator, and after determining the proper depth at the first sampling, to record the length of line used and indicate it by a knot in the line; then drop the sampling bottle always to the same depth from the nail for the bottom sample.

Apparatus.—Salinity samples may be taken either with a special lead-weighted copper salinity bottle such as that used by the S. P. Co., or with any suitable stout glass bottle of 12-ounce to 1-pint capacity, weighted so as to permit its sinking when empty. The common 12-ounce citrate of magnesia bottle is excellent. If a glass bottle is used it must be supplied with a solid stopper, through which a stout wire is driven and clinched on the under side, while the protruding end on the upper side is formed into a small ring. The lowering cord is then tied securely, say a foot from its end, to the ring in the stopper wire, and the end of the cord fastened tightly around the neck of the bottle so as to allow a few inches of slack between neck fastening and stopper ring. The friction of the stopper will permit the lowering of the closed bottle to the desired depth in the water, where it can be unstoppered by a quick jerk of the line. Should premature pulling of the stopper occur, it can be detected by the too early appearance of bubbles due to filling. If the citrate of magnesia pattern is not used, the bottle should in any case be as small-necked as will permit the proper wiring of the stopper, in order to avoid contamination of the sample by inwash of shallow water while raising the bottle.

Storage.—Each sample of water should be transferred from the sampling bottle to a thoroughly *cleaned* and drained storage bottle of approximately the same size, preferably glass stoppered, which should be tag-labeled with the number or name of station, date and hour of sampling, state of tide, whether sample is from top or bottom, and, for the latter, the height from bottom and approximate depth below surface at which taken. Analysis of the samples can then be made at convenience, except that analysis results should be sent in currently, without too great delay.

Shipping.—If the water samples must be transported by common carrier, to the laboratory or otherwise, a case constructed in accordance with the accompanying diagram will be found to combine a high degree of safety and convenience.

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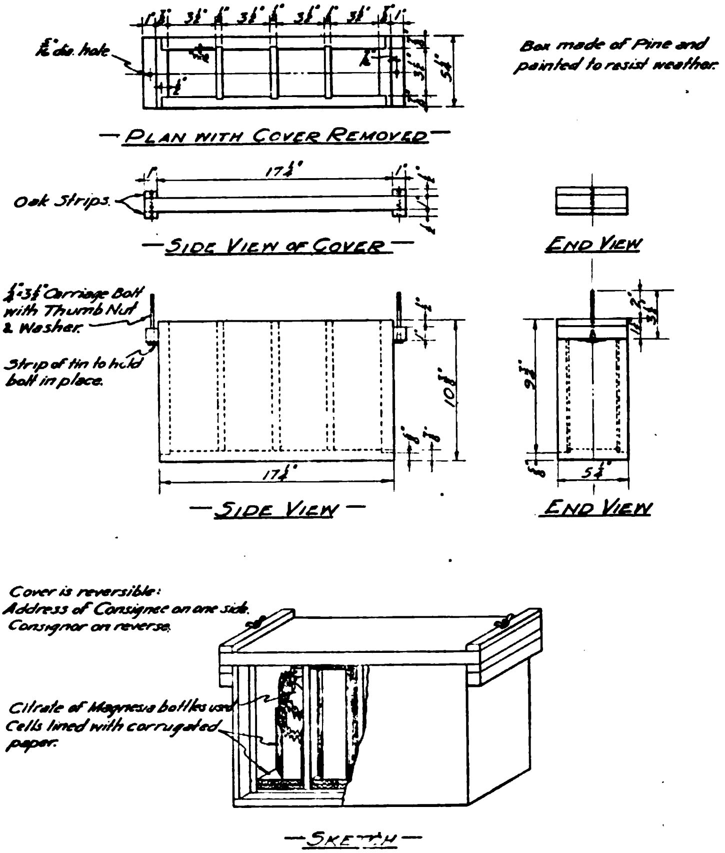
* Address by letter, District Forester, Ferry Building, San Francisco, California, attention C. L. Hill; telephone Kearny 5869.


Box made of Pine and painted to resist weather.
dia. hole
— PLAN WITH COVER REMOVED —
17½"
Oak Strips.
— SIDE VIEW OF COVER —
END VIEW
Carriage Bolt with Thumb Nut & Washer.
Strip of tin to hold bolt in place.
17½"
— SIDE VIEW —
5¼"
END VIEW
Cover is reversible: Address of Consignee on one side. Consignor on reverse.
Citrate of Magnesia bottles used. Cells lined with corrugated paper.
— SKETCH —

SHIPPING BOX FOR WATER SAMPLES
SAN FRANCISCO BAY SALINITY INVESTIGATION
Scale: 1½" : 1'-0"   Date: Dec. 1920
Designed by F. H. Gilman, Asst. Engr. N.W.P.R.R. Co.

Analysis.—The method selected as best adapted to our needs is the Mohr method of determination of chlorine by titration with silver nitrate, with a numerical modification designed to permit the reading of results in parts of chlorine per 1000 parts of water analyzed, from the burette reading of c.c. of silver nitrate solution required for reaction, with the least possible amount of computation.

Preparation of Solutions.—Prepare a standard solution of silver nitrate by dissolving 23.9545* grams of chemically pure crystals of silver nitrate, which has first been carefully dried, in distilled water to make exactly 1000 c.c. Also prepare a 10 per cent solution of chemically pure potassium chromate, which will be used as an indicator to show the end of reaction.

Testing of Standard Silver Nitrate Solution for Standard Strength.—This should be done at frequent intervals as follows: Dissolve 0.0824 grams of chemically pure *dried* sodium chloride in any convenient amount of distilled water. This amount of sodium chloride will require exactly 10 c.c. of standard solution of silver nitrate for complete reaction. Add to the sodium chloride solution a few drops of potassium chromate indicator, as above prepared. Then, drop by drop, from a burette add the silver nitrate solution to be tested, stirring constantly until the appearance of the permanent red color of silver chromate indicates that the reaction is complete. If more or less than 10 c.c. of the silver nitrate solution is required to complete reaction, repeat the test and record the average ratio of standard to actual amount (e.g., if 9.5 c.c. are used, ratio $= 10/9.5 = 1.0526$), to be applied as a correction factor to all burette readings with that lot of solution.

It should be borne in mind that there is a large source of possible error in the judgment of the point at which the red indicator color becomes permanent. The titration should proceed slowly and with great caution as soon as red begins to appear.

To Analyze Water Sample for Salinity.

1. Filter sample of water to be tested, if turbid.
2. Weigh out 5 grams of the filtered sample, on a balance sensitive to 1/10 milligram, and add to it 25 or 30 c.c. of distilled water.
3. Add 10 drops of the 10 per cent potassium chromate indicator.
4. From a burette graduated to 1/10 c.c. add standard solution of silver nitrate, a drop at a time, and stir constantly until the end of reaction is indicated by appearance of permanent red color. Then carefully take burette reading.

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* On the basis of 1920 international atomic weights. This solution strength is based on the amount required for a decinormal solution (16.989 grams) multiplied by the factor 5/3.546, which is derived as follows: In the method for analysis of water, as set forth below, assume the use of a decinormal solution of silver nitrate; then each c.c. of the decinormal solution would represent 0.003546 grams of chlorine in the reaction. Now let a = the number of c.c. of decinormal solution required for complete reaction on b grams of water taken for test. Then

$$\frac{a \times 0.003546 \times 1000}{b} = \frac{a \times 3.546}{b} =$$

parts of chlorine in 1000 parts of water as analyzed. If, now, the strength of the silver nitrate solution be increased to 5/3.546 times that of a decinormal solution, the parts of chlorine per 1000 parts of water will be given by the ratio

$$\frac{a \times 5}{b}$$

or the number of c.c. of standard silver nitrate solution required for complete reaction multiplied by the ratio of 5 over the number of grams of water analyzed. If, then, 5 grams of water be taken for analysis, the parts of chlorine per 1000 of water will be given directly by the number of c.c. of silver nitrate solution required for complete reaction, without further computation, as used in the analysis method.

This analysis should be repeated at least three times on each sample and the average of results taken, unless the first two analyses agree.

5. Assuming that the silver nitrate solution is of standard strength and that 5 grams of water are taken for analysis, then the number of c.c. of silver nitrate solution required for complete reaction will represent the parts of chlorine per 1000 of water analyzed, without further computation.

6. By reference to the international hydrographic tables* the parts of chlorine per 1000 (column 1, marked "Cl") can be read directly into total salinity (column 2, marked "S"). This "salinity" represents the oceanic portion of bay waters only and neglects the stream and seepage, or land water, contributions, since the marine borers are only adapted to the normal saline complex of sea water.† All salinity results for this survey should be represented in terms of this calculation of total salinity, in parts per 1000, in accordance with these tables.

Current Record and Disposition.—The results of each weekly or other periodic analyses should be tabulated in triplicate against the data obtained from the tag-label of each water sample. One copy may then be kept by the coöperator, while the remaining two are to be mailed to the U. S. Forest Service, Ferry Building, San Francisco, Calif., attention of C. L. Hill, by whom one set of all analyses will be sent to Professor C. A. Kofoid at the University of California for use in the biological studies.

II. TEST PIECES

For the purpose of recording the activity of borers, test pieces of untreated timber will be planted at points to be selected by the Committee or the engineer of the survey. Specifications for making these test pieces are given on the accompanying diagram. The pieces can be put down securely by pushing the end slightly into the mud and tacking the top to a convenient point on the structure by which the test station is located.

The use of such test pieces, as described below, is the best means so far devised to make possible continuous information respecting the inception, character, and rate of progress of a marine borer attack at a specified point, and therefore a judgment respecting the probable condition of and the degree of danger to adjacent structures. For this purpose one test piece should be installed each month, beginning preferably, in this climate, with the calendar year or some time during the rainy season, while the salinity is lowest in bay areas affected by land water discharge. Each month there should then be taken off from all the test pieces previously installed the bottom saw-cut section (or that one whose position has been next above the mud line), together with the attached redwood block. Except in the case of the first test piece put down, there is no need of keeping a given piece in position more than one year. There will then be obtained each month as many test sections as the number of months during which the test has been in progress, up to one year, and after that a continuing series of 12 sections, of which one was installed during each month of the preceding year. To give continuing information on the relative intensity of

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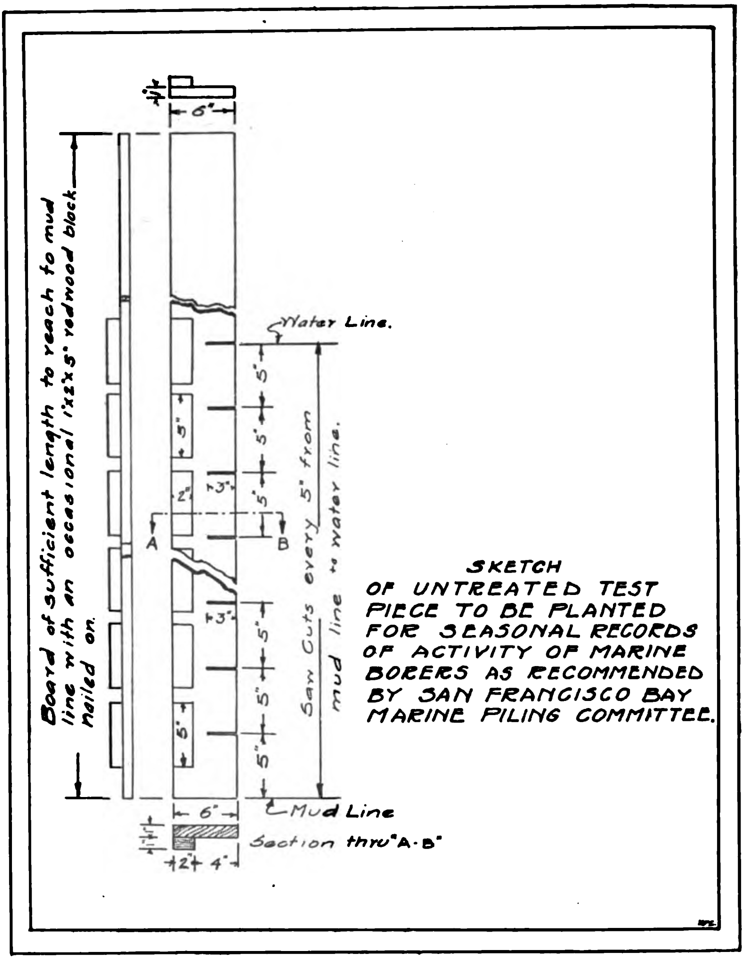
* "Hydrographische Tabellen" by Martin Knudsen; prepared under the authority and direction of the International Council for the Exploration of the Sea. Published by G. E. C. Gad, Copenhagen, 1901. The formula on which these tables are based is: $S = 1.8050 \text{ Cl} + 0.030$.

† Therefore determination of the salinity of brackish waters by the weight of solids left on evaporation is not valid for the purposes of the Marine Borer Survey.


Board of sufficient length to reach to mud line with an occasional 1"x2"x5" redwood block nailed on.
6"
1"
Water Line.
5"
5"
3"
2"
A
B
Saw Cuts every 5" from mud line to water line.
Mud Line
Section thru "A-B"
2"
4"
1"

SKETCH
OF UNTREATED TEST
PIECE TO BE PLANTED
FOR SEASONAL RECORDS
OF ACTIVITY OF MARINE
BORERS AS RECOMMENDED
BY SAN FRANCISCO BAY
MARINE PILING COMMITTEE.

attack at different levels, the first piece put down should have the saw-cuts extend not over half through the width of the piece, so as to leave a substantial strip to support all the remaining saw-cuts at their original level as long as it is not destroyed by borers. The value of such a record, as much from the engineering and commercial standpoint as from the scientific, is many times more than its cost.

For purposes for which the above method is deemed too elaborate or costly, useful information can be secured by installing two test pieces at each station. The monthly sections are then taken from one piece and the other is left intact, an examination of the latter being made whenever sections are taken from the former.

Test stations should be located at the points of most rapid and severe attack. Such points can usually be anticipated as the points of most rapid current, or in the absence of current, of tidal flow, and in the deeper water.

Test sections, as removed, should be labeled with the name or other designation of the station, the test piece and saw-cut section numbers, and the dates of installation and removal. Those to be used for the purposes of the San Francisco Bay Marine Piling Survey should be wrapped securely and mailed to Professor C. A. Kofoid, East Hall, University of California, Berkeley, California.

III. SPECIMENS OF WOOD AND BORERS

Specimens showing the borers present, or illustrating the nature and progress of attack, are desired from as many localities as possible. Such specimens will be valuable for:

1. Piling or other wooden structures which will throw light on date of invasion or rate of destruction in any locality.
2. Invaded piling or structures giving similar information, especially in territory hitherto exempt from borers.

Specimens should be accompanied by complete data. The specimens may be of two kinds:

1. Wet specimens containing the living or undried animals. These should not exceed 12 inches in length, and should be selected to exhibit typical areas of heavy destruction of the different kinds of borers. They may be from either service piles and timbers or planted check timbers. Specimens should be sawed and split out with care and placed promptly in formalin (or formaldehyde) in a tub or pail. Formaldehyde can be obtained at any drug store and comes of a strength of approximately 40 per cent. A dilution to about 1 part formalin (as purchased) to 20 parts of water (salt or fresh) will pickle the animals in place in the wood in twenty-four hours. The sample may be left indefinitely in the formalin without harm. For shipment the sample may be wrapped while wet in a heavy covering of newspapers and shipped promptly, preferably in a tin or other tight box.
2. Dried sections not exceeding 18 inches in length, with invading borers dried in place, or their shells, whenever possible. Specimens should be protected for shipping by wrapping with burlap or a heavy covering of paper and suitably boxing them. Specimens of this kind have a great deal of value, if properly prepared and protected, and should not be neglected, especially when wet specimens containing the living animals are not available.

All specimens for the determination of the borers at work in each locality should be sent by parcel post or express, prepaid, to Professor C. A. Kofoid, East Hall, University of California, Berkeley, California.

IV. RECORDS OF PILING OR OTHER STRUCTURES ATTACKED BY MARINE BORERS IN SAN FRANCISCO BAY OR TRIBUTARIES

Authentic records giving the essential information in regard to past developments in borer infestation will be invaluable. Such records, like the specimens, will be valuable for either:

1. Piling or other wooden structures which will throw light on the date of invasion or rate of destruction in any locality.

2. Invaded piling or other structures, giving similar information, in territory hitherto exempt from borers.

Bulky reports, or other documents, which it is not feasible to copy. If by any chance you have an extra copy which you can forward to the U. S. Forest Service, Ferry Building, San Francisco, California, attention of Mr. C. L. Hill, do so. If you have no such extras, please send to Mr. Hill a list of the reports which you have, with brief description, giving for each title, material covered if not sufficiently given by the title, author, date, number of pages, and whether you could send it to the Forest Service as a loan, if desired, and for how long, or if not, it could be used for consultation at your office.

Reports made or which you could make specifically for this survey. Are there any important or interesting phases of the marine borer infestation which you could report on for the benefit of those who are working on the survey? Advise Mr. Hill about it. Such records or reports should cover, or at least not overlook, all the points listed in the questionaire recently issued, and which were, with slight modification, as follows. [Omitted here; see Appendix B.]

In addition to the above information (or if that has already been reported, a reference to such report), these reports should give all possible light respecting kind of borer and nature of working (especially by specimens, on which see above); location of working or of marignal and most severe zones of attack, respectively, with respect to mud line, low and high tide depth, etc.; as well as nature of exposure with respect to tide currents, fresh water seepage, sewage influx, debris breeding centers, or any other factors which you believe may have affected the life and attack of the borers in the material in question.

Whenever possible all reports prepared specially for this survey should be prepared in triplicate, so that one copy can be sent to the U. S. Forest Service, Ferry Building, San Francisco, attention of C. L. Hill, and another to Professor C. A. Kofoid, East Hall, University of California, Berkeley, California.

Msicellaneous observations and notes. Notes on anything which interests you in respect to the marine borer situation will probably be of interest for the survey, and may be exactly the point missed by others. Dictate memoranda on all such points and send them in to the Forest Service. We can better afford to have some such material which is not used than to miss important information by neglecting such notes.

Photographs. Good photographs are greatly desired. In no other way can many things be told so plainly. Many photographs will be taken in the course of the survey; but if we knew what you had it might save time and money; and you may have a better picture of some important feature than anybody else will ever take. If your collection is not too extensive, can you have copies, carefully labeled, made and sent to Mr. Hill at the Forest Service? If that is not feasible, will you write him about it, so that arrangements can be made to look over your collection and get copies of the items most essential for our purpose?

Issued October, 1920, for the San Francisco Bay Marine Piling Committee of the American Wood-Preservers' Association, by Subcommittee on Instructions:

E. M. BLAKE,
F. D. MATTOS,
Professor C. A. KOFOID, University of California,
T. G. TOWNSEND, Forest Products Engineer, Engineer of Survey,
C. L. HILL, in Charge, Office of Forest Products, U. S. Forest Service, San Francisco, *ex officio* as Executive Officer of the Committee.

The plates which follow were made from photographs furnished by coöperators as follows:

Plate 1, figure 1, by the Union Oil Company.

Plates 2 and 24 by the Shell Oil Company.

Plate 3 by the Moore Shipbuilding Company.

Plate 6 by Mr. Howard C. Holmes, Consulting Engineer.

Plates 15, 21, 26 fig. 3, and 27 by the Southern Pacific Company.

Plate 23 by the U. S. Navy Department, Mare Island Yard.

Plates 25 and 30 by the California-Hawaiian Sugar Refining Company.

The remaining plates* are from photographs made by or under the direction of the following members of the Committee:

Mr. F. D. Mattos of the Southern Pacific Company.

Mr. T. G. Townsend of the U. S. Forest Service.

Professor Charles A. Kofoid of the University of California.

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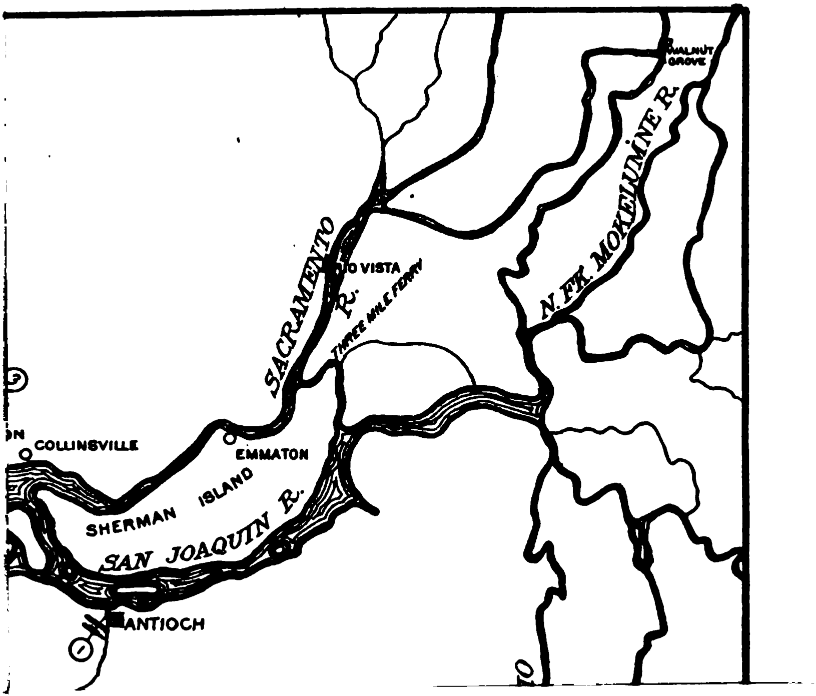
* Except plate 26, figs. 1 and 2, from Calman, as credited in figure descriptions.

NUMBERS AND NAMES FOR MAP OF SAN FRANCISCO BAY AND TRIBUTARIES

1. Antioch—A. T. & S. F. R. R. dock; Municipal dock.
2. Pittsburg—Small docks.
3. Dutton—S. F.-Sacramento R. R. drawbridge.
4. Dutton—S. F.-Sacramento R. R. trestle.
5. Chipps—S. F.-Sacramento R. R. ferry slip.
6. Mallard—S. F.-Sacramento R. R. ferry slip.
7. Bay Point—Coos Bay Lumber Co.; Pacific Coast Shipbuilding Co.
8. Avon—Associated Oil Co.
9. Martinez—General Chemical Co.; Electrolytic Zinc Co.; Mountain Copper Co.; American-Oriental Co.; Shell Co. of California; Municipal wharf and ferry.
10. Benicia—U. S. Arsenal pier.
11. Benicia—Kullman-Salz Co.; C. W. Hume & Co.; S. P. R. R. river dock; Municipal wharf and ferry.
12. Benicia—S. P. R. R. ferry
13. Benicia—U. S. Shipping Board pile boom
14. Port Costa—Associated Oil Co.; S. P. R. R. ferry; McNear warehouses.
15. Port Costa—Granger's dock.
16. Crockett—Fort Bragg dock; Banker's dock; California and Hawaiian Sugar Refining Co.; 6-Minute ferry; Matson Navigation Co.; Port Costa Lumber Co.
17. Vallejo Junction—S. P. R. R. ferry to Vallejo.
18. Selby—American Smelters and Securities Co. dock (condemned).
19. Oleum—Union Oil Co.
20. Rodeo—6-Minute Ferry to Vallejo.
21. Hercules—Hercules Powder Co.; Fernandes wharf.
22. South Vallejo—6-Minute Ferry to Crockett.
23. South Vallejo—U. S. Navy dyke 9; Sperry Flour Co.; S. P. R. R. ferry to Vallejo Junction; ferry to Rodeo.
24. Vallejo—Various small docks and bulkheads; Monticello Steamship Co.; San Francisco, Napa and Calistoga R. R.; S. P. R. R. ferry to Vallejo Junction; ferry to Navy Yard.
25. Vallejo—U. S. Navy, causeway.
26. Napa Junction—Associated Oil Co.
27. Mare Island—U. S. Navy structures.
28. Mare Island—U. S. Navy, dyke 12.
29. Black Point—Northwestern Pacific R. R. bridge; State Highway bridge.
30. Petaluma—Small docks in Petaluma; Northwestern Pacific R. R. bridge.
31. Point San Pablo—Richmond Belt Railway.
32. Point San Pablo—Standard Oil Co.
33. Point San Pablo—California Wine Growers' Association.
34. Point Richmond—Standard Oil Co.
35. Point Richmond—A. T. & S. F. R. R. ferry.
36. Point Richmond—Richmond Municipal wharf.
37. Tiburon—Northwestern Pacific R. R. ferry.
38. Sausalito—Northwestern Pacific R. R. ferry.
39. Angel Island, Fort Baker, Fort Barry, Fort Scott, Alcatraz Island, Presidio, Fort Mason—U. S. Army docks.
40. Goat Island—U. S. Naval Training Station.
41. San Francisco—State Harbor Commission piers (odd numbers).
42. San Francisco—Ferry slips.
43. San Francisco—State Harbor Commission piers (even numbers).
44. Oakland—Key Route pier (S. F. & O. T. Rys.).
45. Oakland—Union Construction Co.; Albers Milling Co.
46. Oakland—S. P. R. R. ferry.
47. Oakland—Western Pacific R. R. ferry.
48. Alameda—S. P. R. R. ferry.
49. Oakland—Moore Shipbuilding Co.
50. Oakland—Structures in Estuary.
51. Alameda—Bethlehem Steel Corporation shipyard.
52. Alameda—Alameda County bridge to Bay Farm Island.
53. Alameda—Alameda Power House pier.
54. Hunters Point—State pile boom.
55. Hunters Point—Drydock.
56. South San Francisco—Shaw-Batcher shipyard.
57. Dumbarton—S. P. R. R. Dumbarton cut-off.
58. Islais Creek—Hammond Lumber Co. pile boom.
59. India Basin—Sewer outlet.
60. South Basin—Bay View sewer outlet.


WALNUT GROVE
N. FK. MOKELUMNE R.
SACRAMENTO R.
IO VISTA
THREE MILE FERRY
N
COLLINSVILLE
EMMATON
SHERMAN ISLAND
SAN JOAQUIN R.
ANTIOCH
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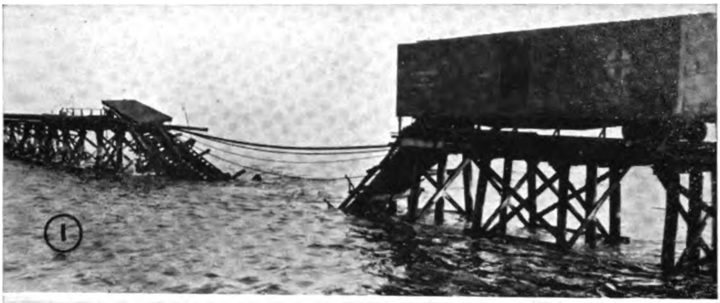
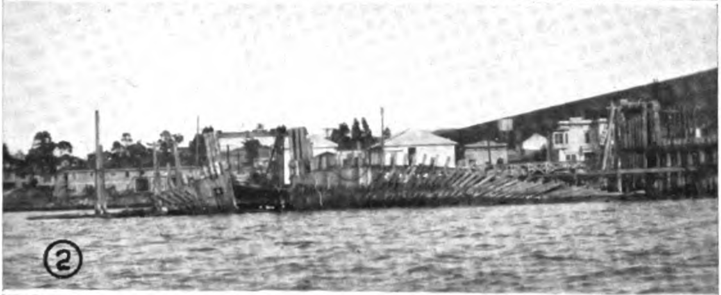




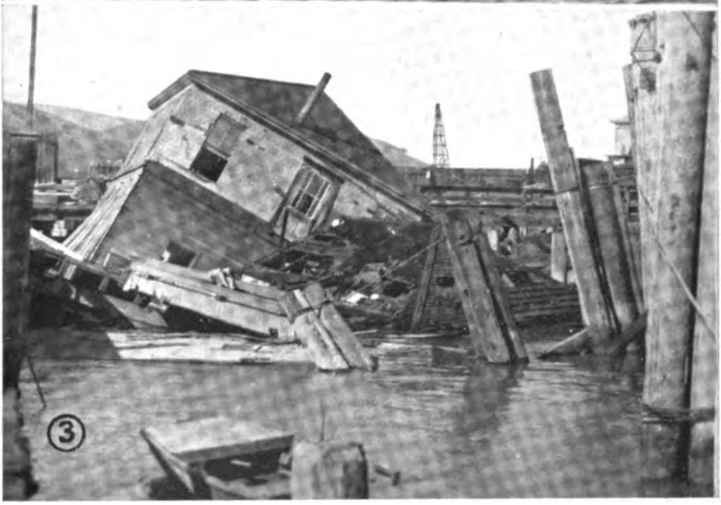
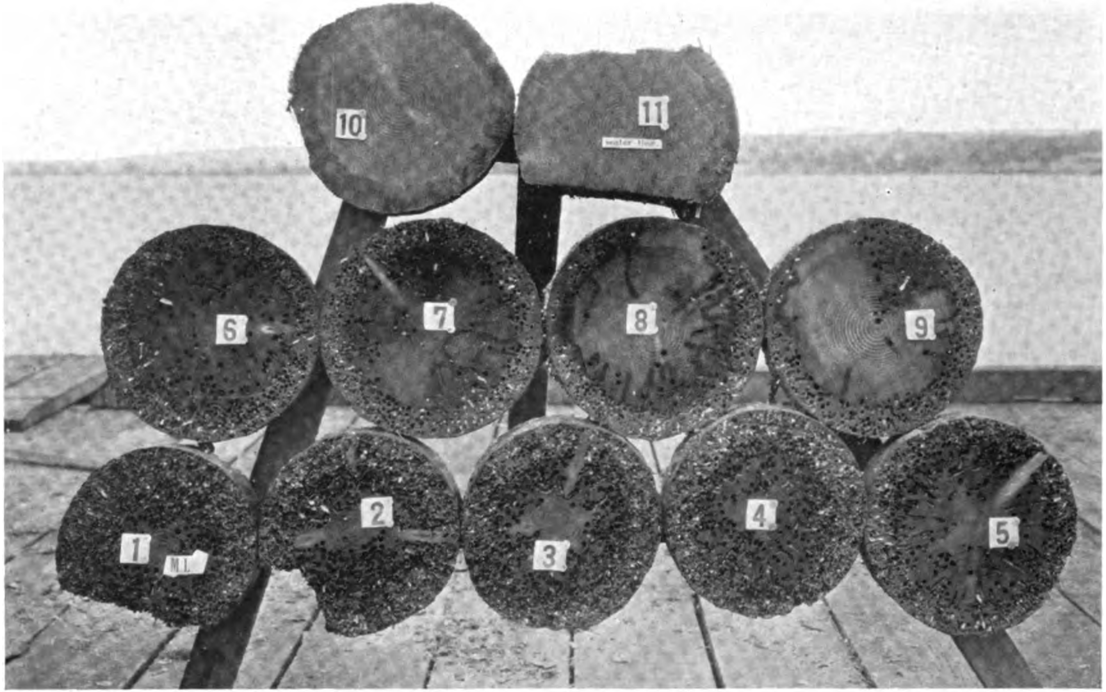


PLATE 1

Fig. 1. One of the first docks which failed. Oleum, California, October 8th, 1919. Several loaded freight cars were plunged into the bay.

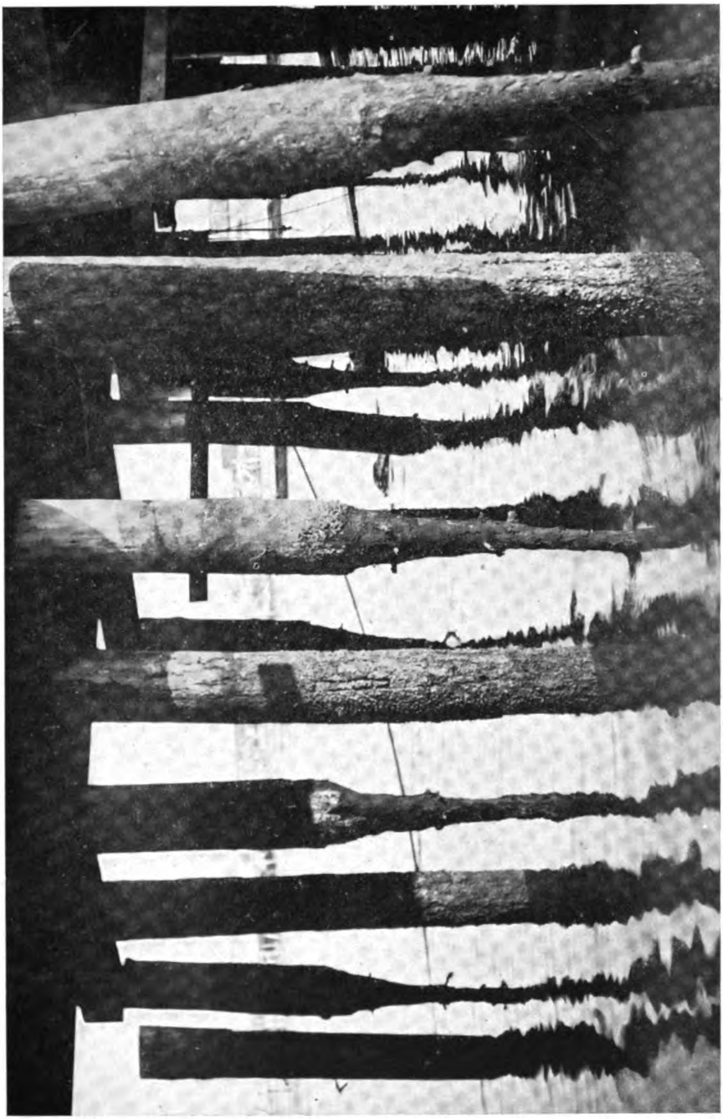
Fig. 2. Ferry slip at South Vallejo, failed November 4th, 1920.

Fig. 3. Municipal Wharf and house, Benicia, California. Collapsed October 7th, 1920.



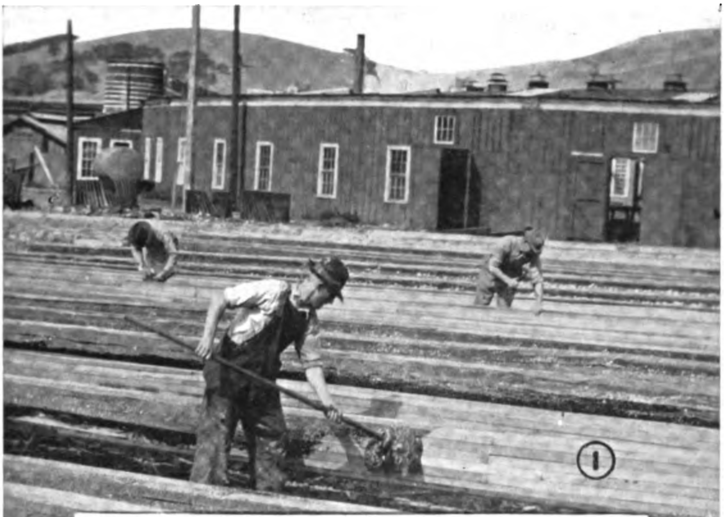
Fender pile, Shell Oil Company dock, Martinez, California. Sections three feet apart, mud-line to high water. November, 1920. Note deeper penetration on down-stream (right side) and offshore (lower) exposure.

PLATE 2



Untreated Douglas fir piling in Oakland Estuary, destroyed by *Limnoria*. Good piles shown are replacements.

PLATE 3



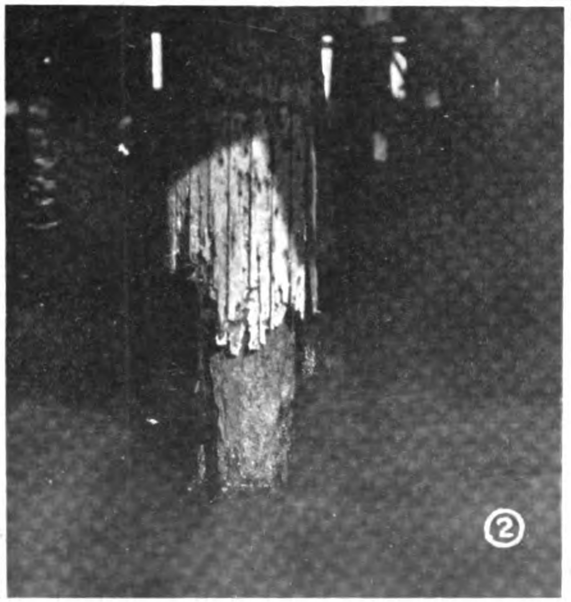
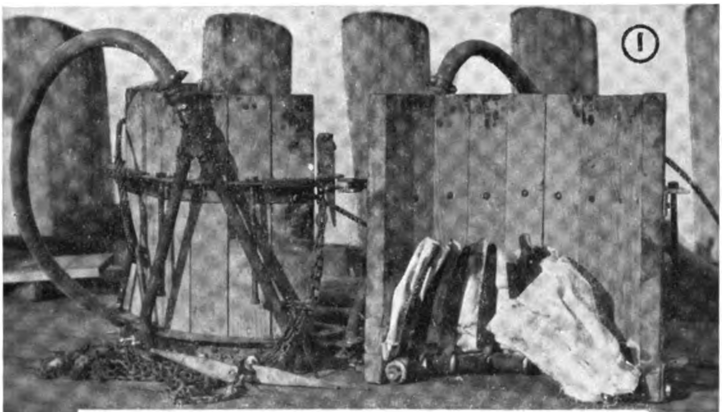


PLATE 4

Fig. 1. Piling being protected by Paraffine Paint method. N.W. P. R.R., 1920.

Fig. 2. Pile originally protected by paint, felt and battens, destroyed by *Limnoria*.



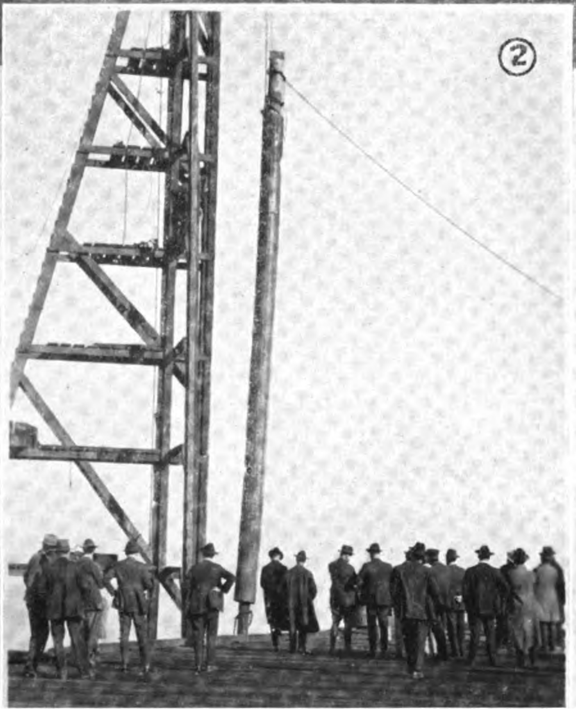
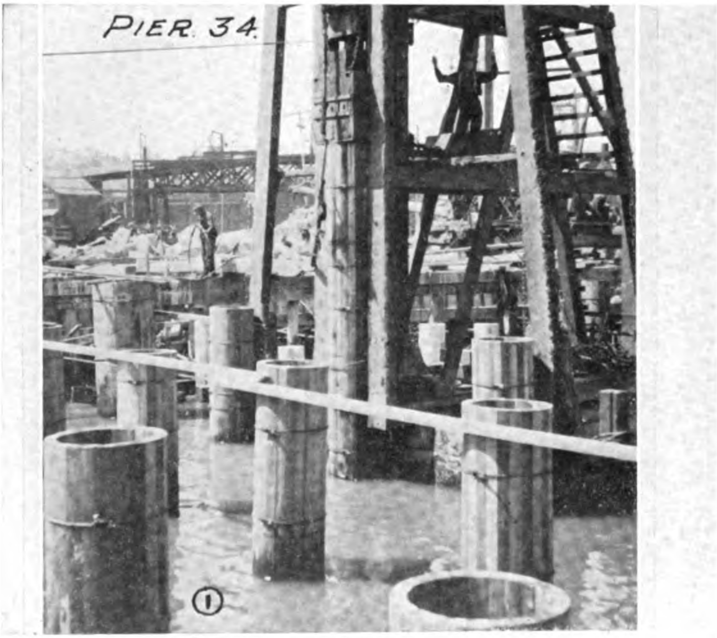


PLATE 5

Fig. 1. Lower forms used in Camp process. Note metal fingers supporting canvas web, to keep concrete from dropping through.

Fig. 2. Pile jacketed with cement by Camp process, being pulled for examination.



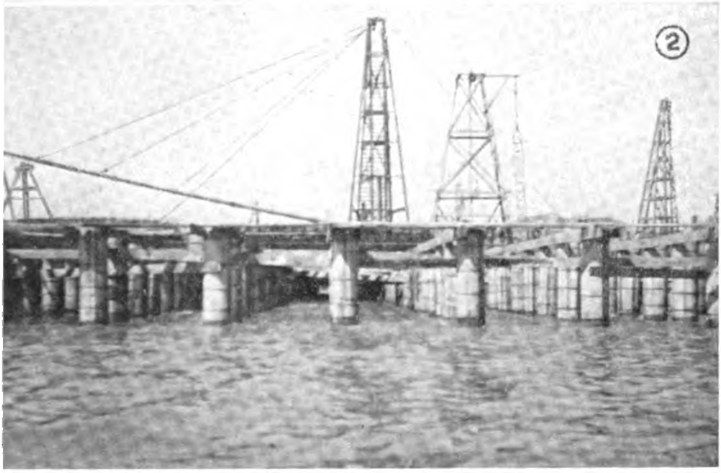
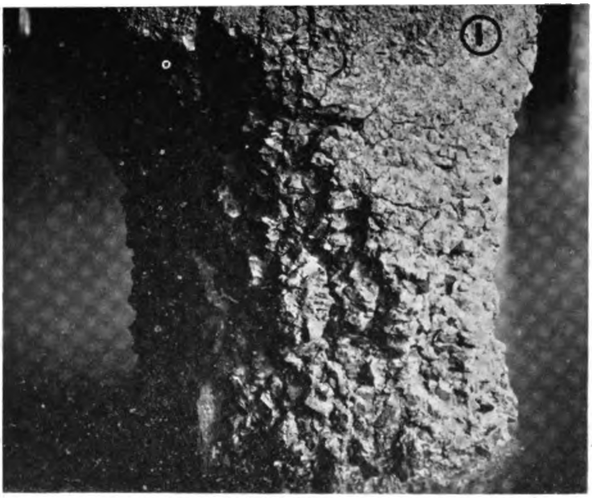


PLATE 6

Fig. 1. Holmes wooden stave cylinders being driven at Pier 34, San Francisco.

Fig. 2. Outer end of Pier 34, San Francisco, during construction, showing Holmes cylinders.



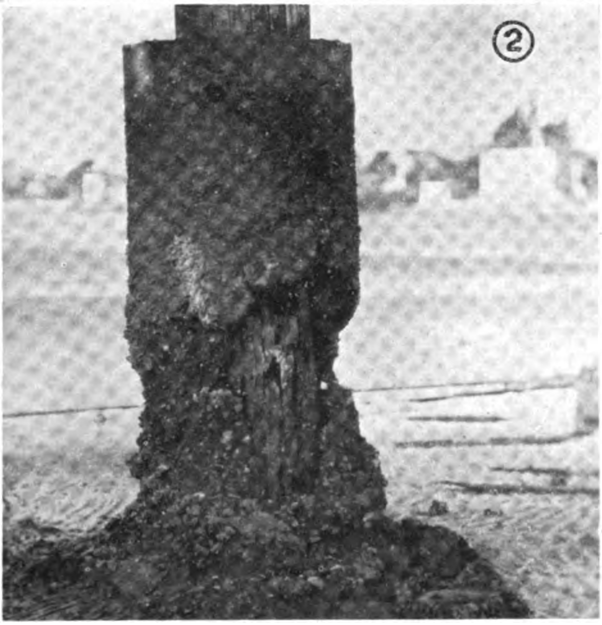


PLATE 7

Fig. 1. Disintegration in concrete composite pile. Probably a result of poor workmanship.

Fig. 2. Disintegration in concrete jacket placed on pile previously covered by battens and paint. Pile attacked by *Limnoria* where coverings have failed. Most of the concrete jackets in this pier were good.

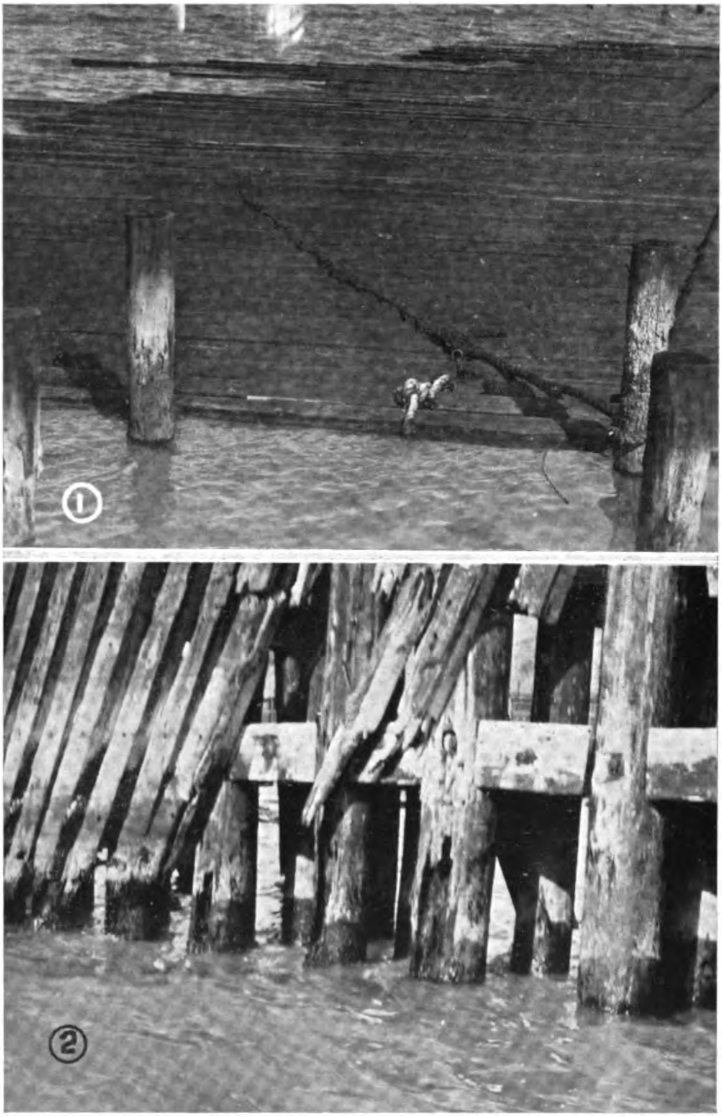


PLATE 8

Fig. 1. A raft of creosoted piles chained together by means of rafting dogs. Untreated wood will be exposed to attack when the dogs are pulled out, where the holes come in the water section of the piles.

Fig. 2. Creosoted ferry slip piling, attacked by *Limnoria* where creosoted zone was cut through in construction.

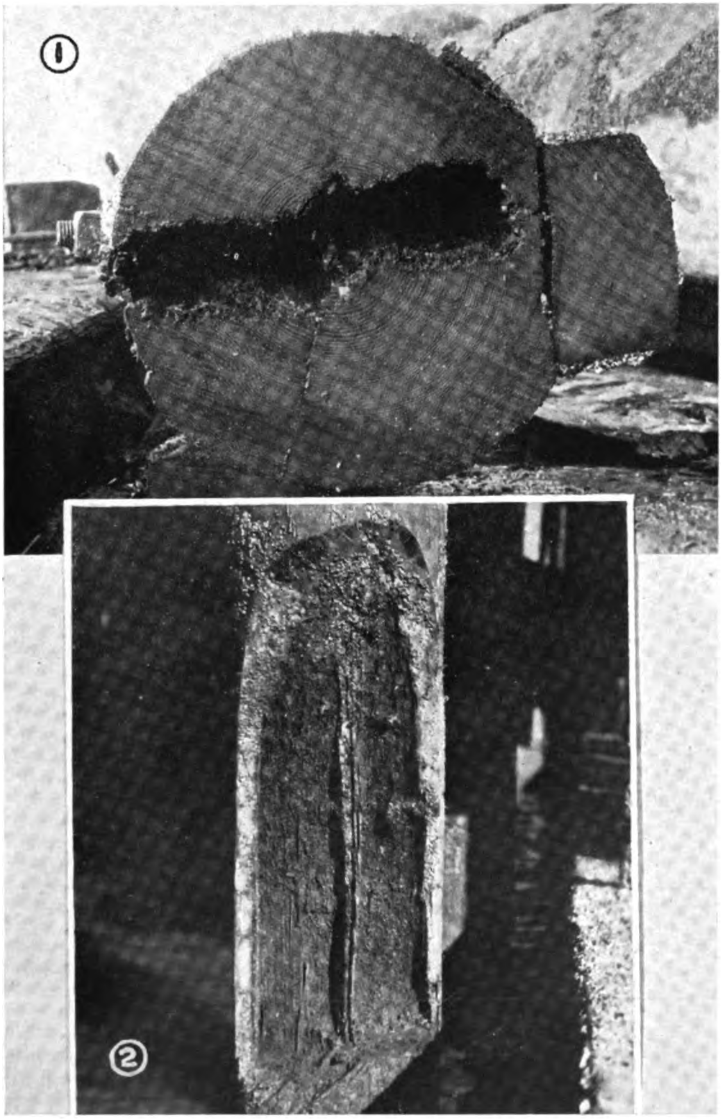
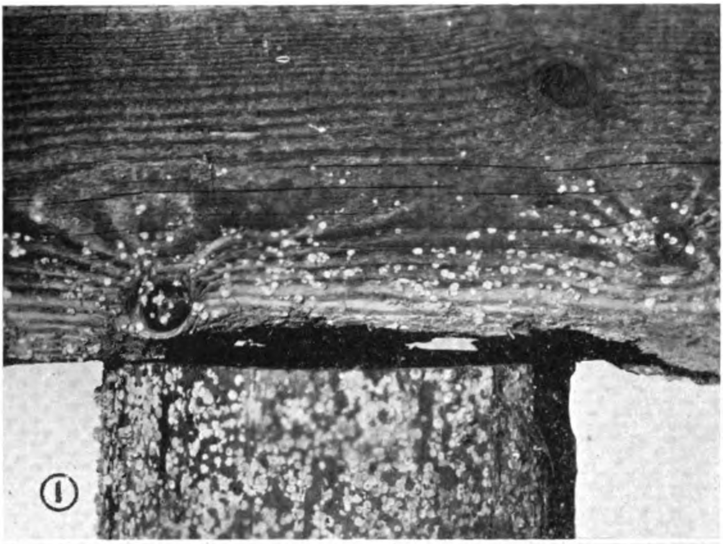


PLATE 9

Fig. 1. Bolt hole in creosoted fender pile, enlarged by *Limnoria.*

Fig. 2. Creosoted pile, attacked within five years by *Limnoria* in a spot exposed by chopping.



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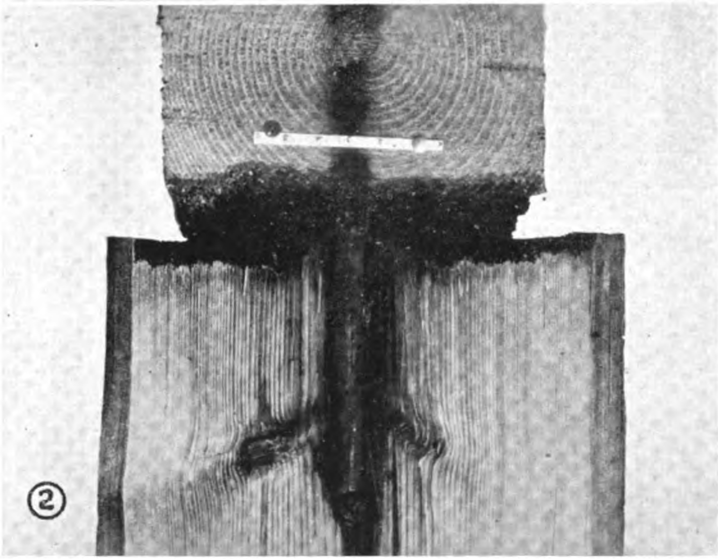

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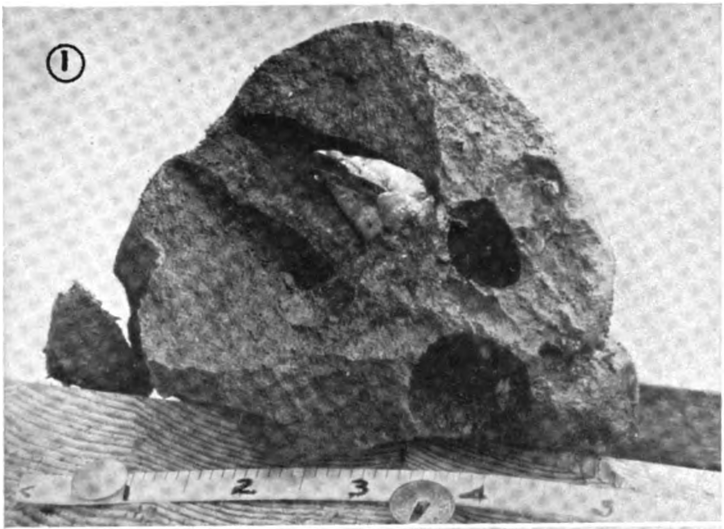
PLATE 10

Fig. 1. Creosoted pile cut off too close above the water. *Limnoria* attacking top of pile and the corbel. High water point is indicated by the barnacle line.

Fig. 2. Section vertically through center of pile head and corbel shown in fig. 1. Note the creosoted shell not yet attacked.



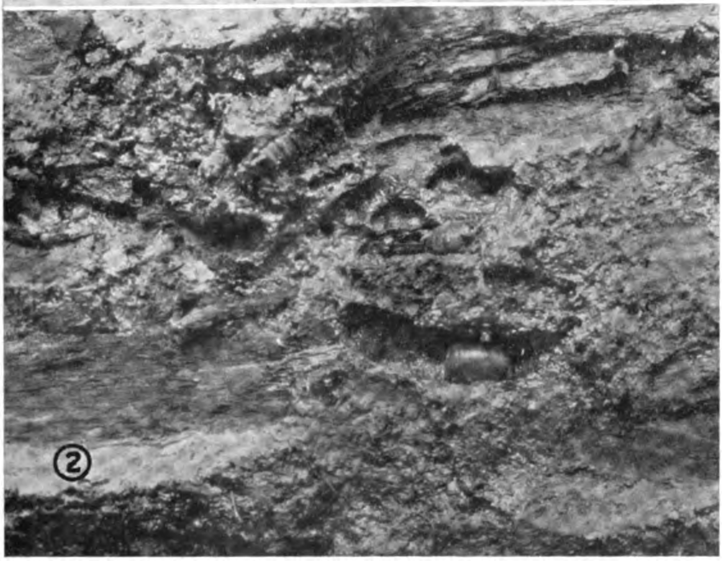
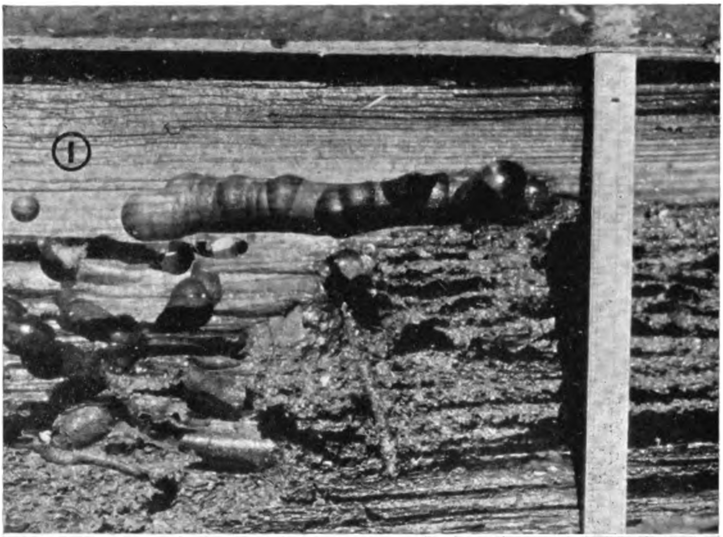


PLATE 11

Fig. 1. *Pholadidea gabbi* Conrad, a boring mollusk from a loose block of sandstone at Fort Mason.

Fig. 2. *Sphaeroma pentodon* working on surface of an untreated pile in a thick scum of crude oil in Monticello S.S. Company's wharf at Vallejo, California, November 9, 1920.



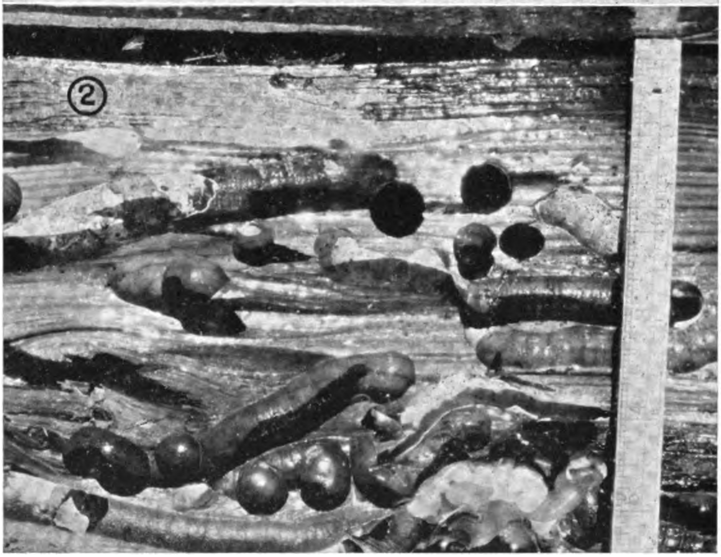
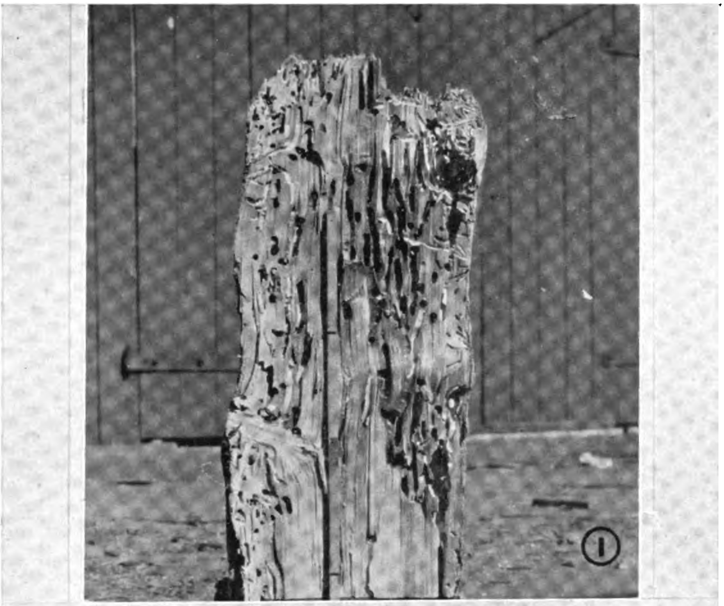


PLATE 12

Fig. 1. Creosoted Douglas fir pile from Pier 7, San Francisco, destroyed near the mud-line by *Xylotrya* and *Limnoria*. Note deviating direction of *Xylotrya* burrow.

Fig. 2. The same, *Xylotrya* burrows only, within creosoted zone. Note changes in direction.



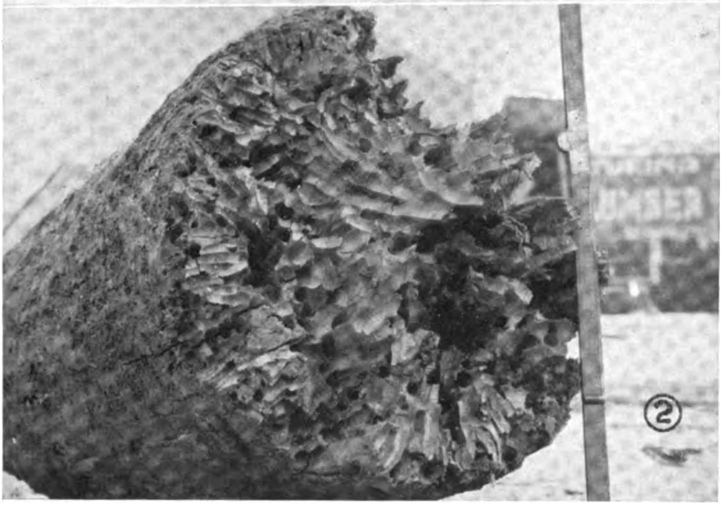
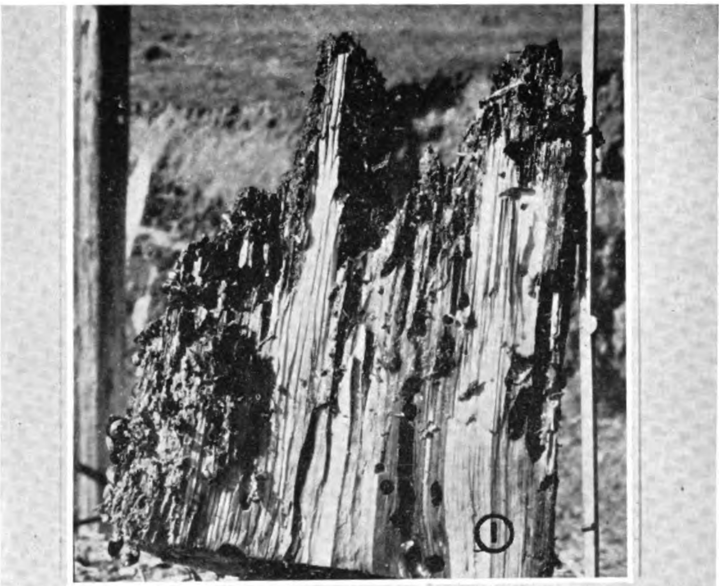


PLATE 13

Fig. 1. Untreated Douglas fir pile from Oakland Municipal Quay, east of Grove Street sewer, driven 1913, removed October, 1920. Destroyed at mud-line by *Xylotrya*, surface eroded by *Limnoria*.

Fig. 2. The same, end view.



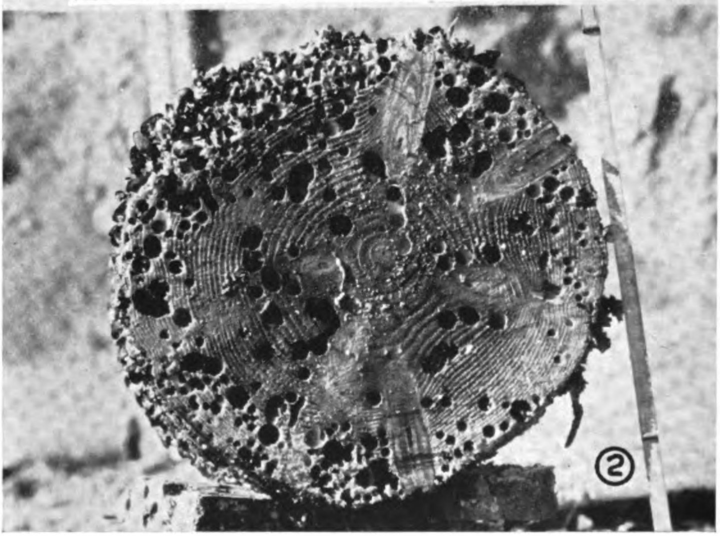


PLATE 14

Fig. 1. Dolphin pile from Richmond Municipal Pier, driven December, 1917, broken out July, 1920. Note large tubes of *Xylotrya* and smaller ones of *Teredo navalis,* and erosion by *Limnoria* at breaking level. *Sphaeroma* also present. Breaking zone exposed at low tide.

Fig. 2. Section of same pile, one foot above break.

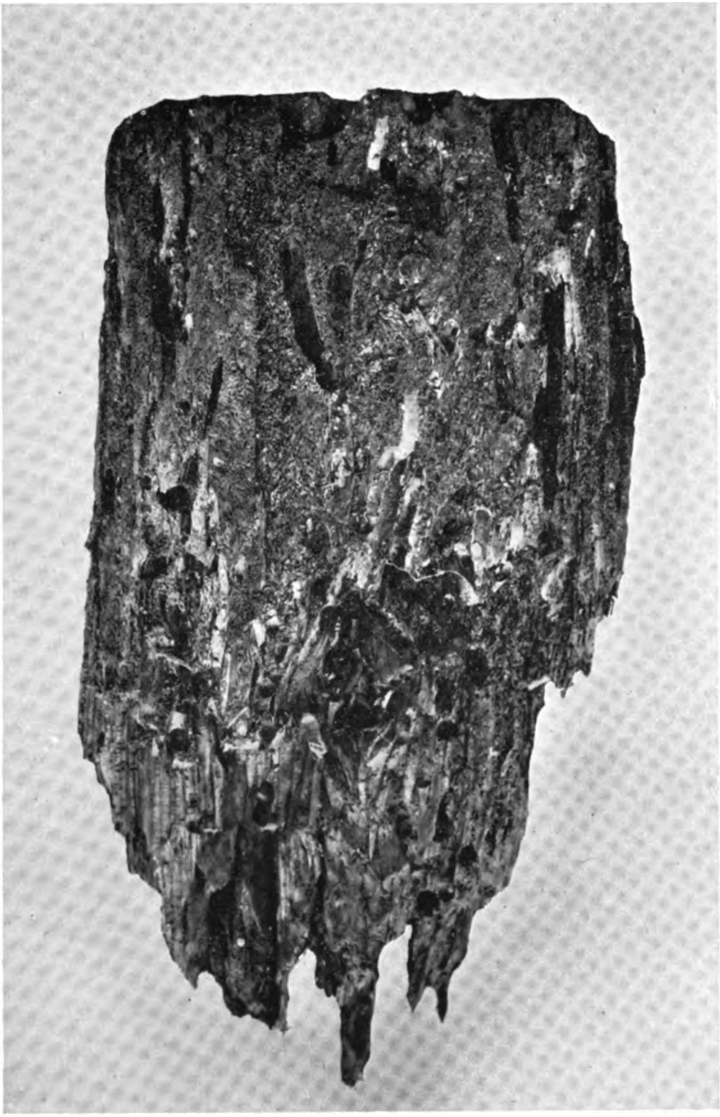


PLATE 15

Untreated Douglas fir pile from 16-pile dolphin at Southern Pacific Alameda Mole, driven February, 1919, removed November, 1920, on account of destruction at mud-line by *Xylotrya*, *Limnoria* and *Teredo navalis*.

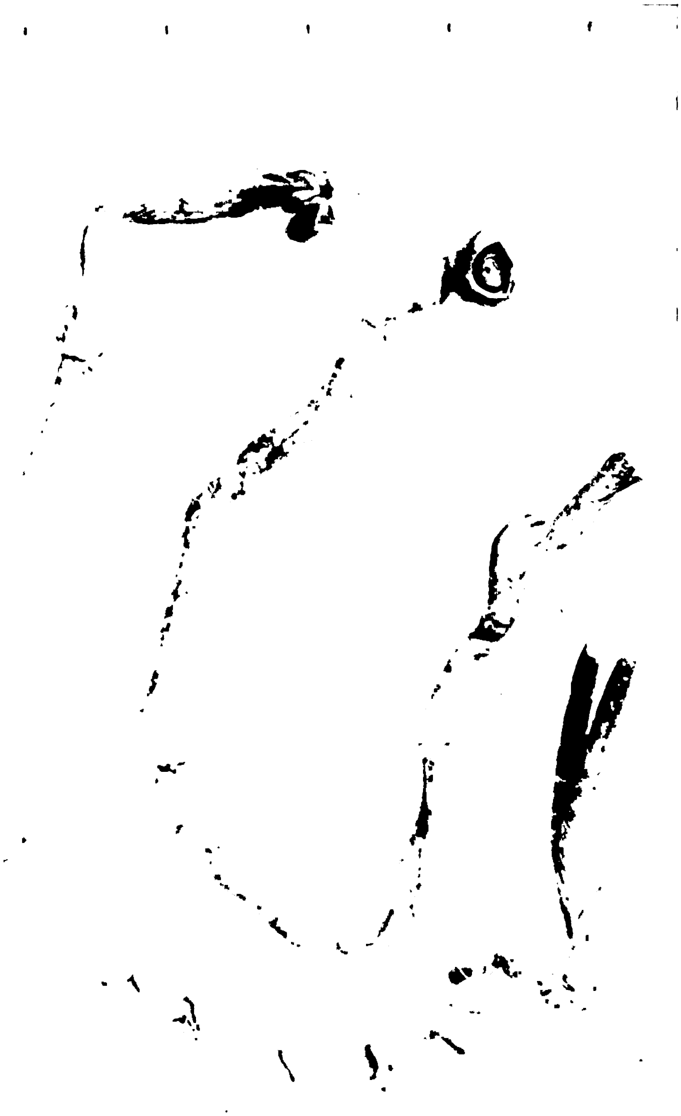


PLATE 16

Xylotrya setacea Tryon, entire animal removed from burrow.

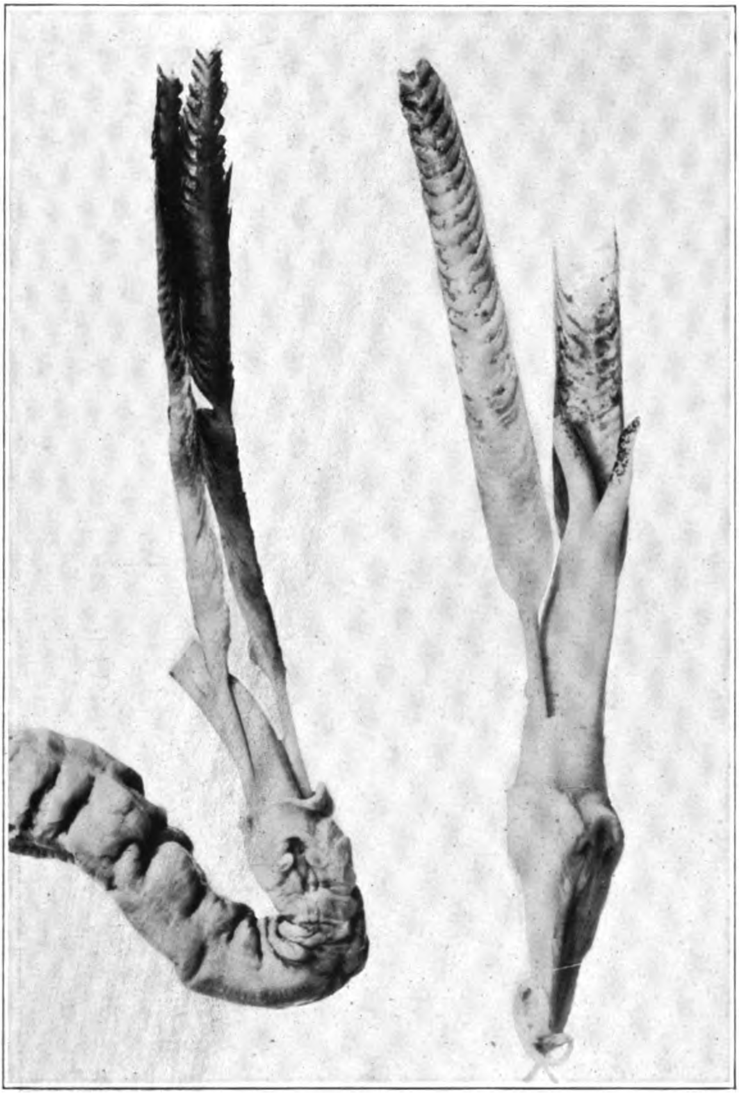
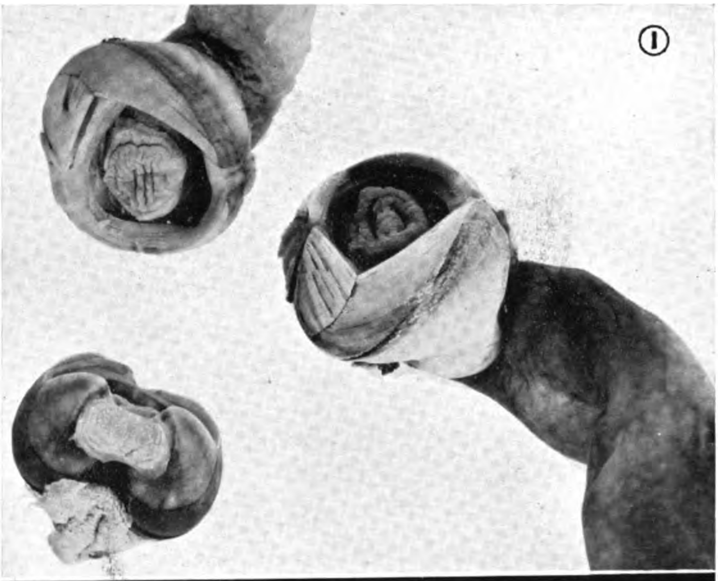


PLATE 17

Pallets and siphons of *Xylotrya setacea* Tryon. Magnified slightly.



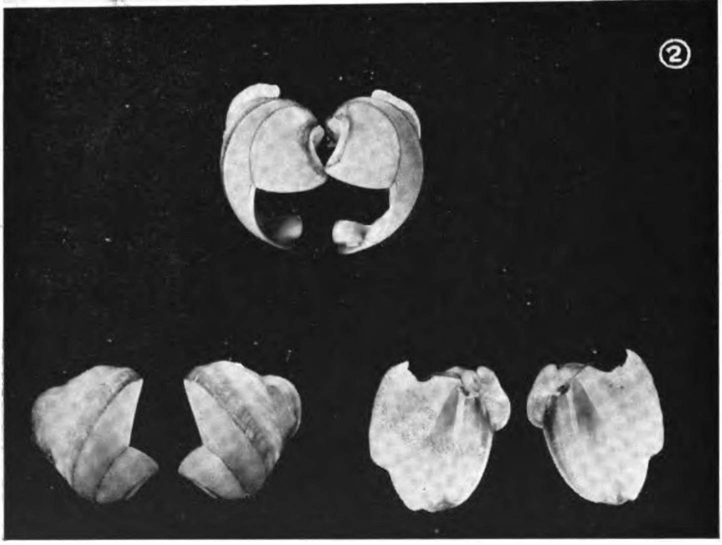


PLATE 18

Fig. 1. Anterior end of *Xylotrya setacea* Tryon, showing shell and foot. × 2.5.

Fig. 2. Shells of same, slightly enlarged.

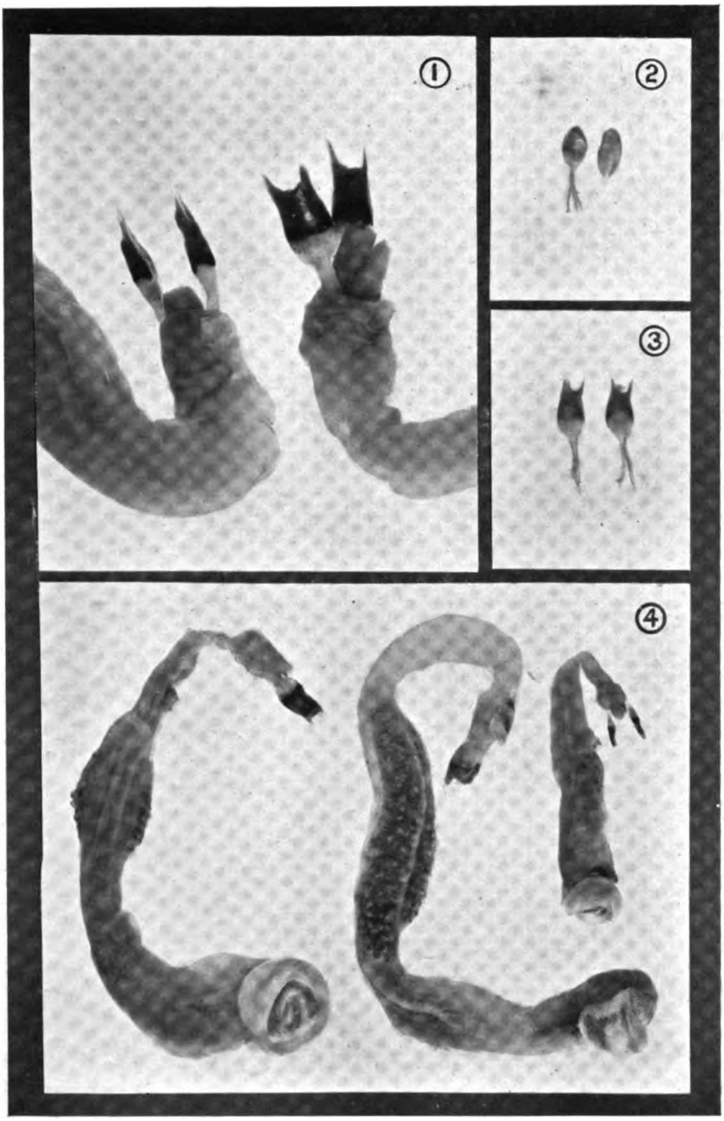


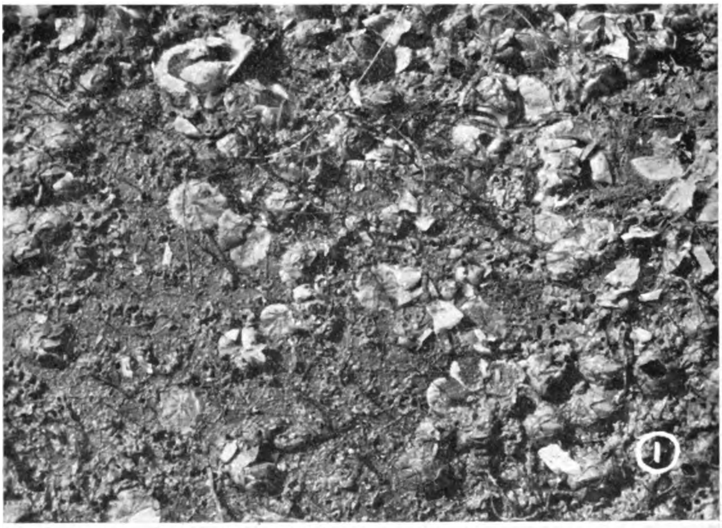
PLATE 19

Teredo diegensis Bartsch.

Fig. 1. Posterior end showing pallets and siphons. Enlarged.

Figs. 2 and 3. Pallets. Enlarged.

Fig. 4. Entire animal, showing shell and brood sac with enclosed larval stages. Enlarged.



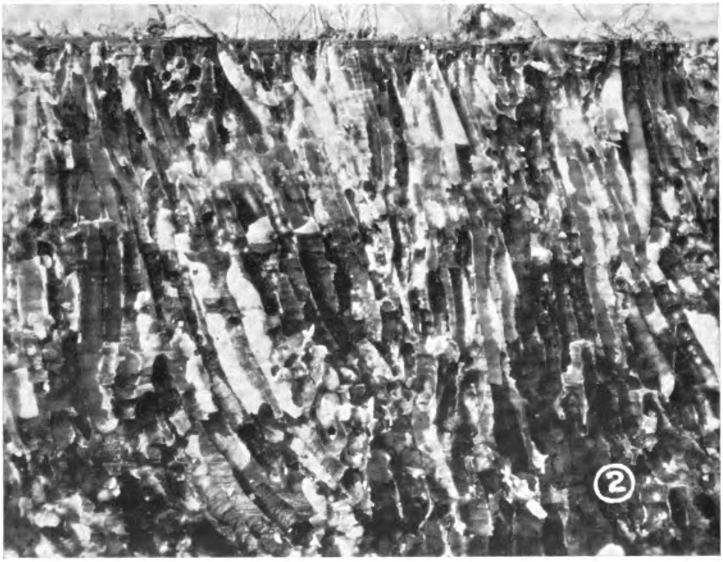


PLATE 20

Fig. 1. Surface of an untreated fender pile from wharf of Mountain Copper Company, Martinez, California, pulled November 11, 1920, showing barnacles and dead stems of hydroids. Openings into burrows of *Teredo navalis* appear as minute pores between the barnacles. Natural size.

Fig. 2. Radial section through same pile, outer part of four-inch penetration. Natural size.

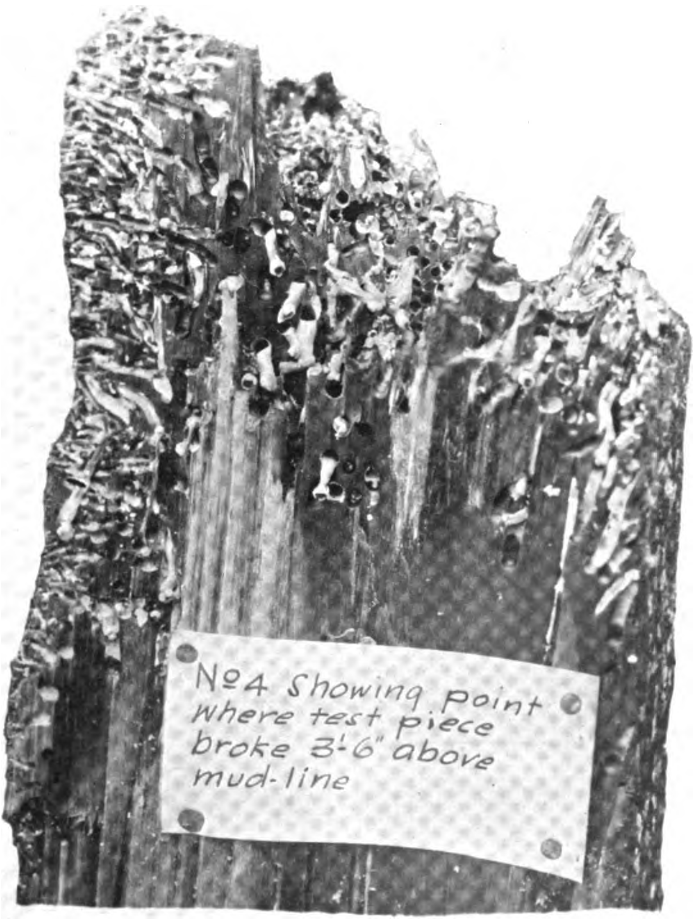
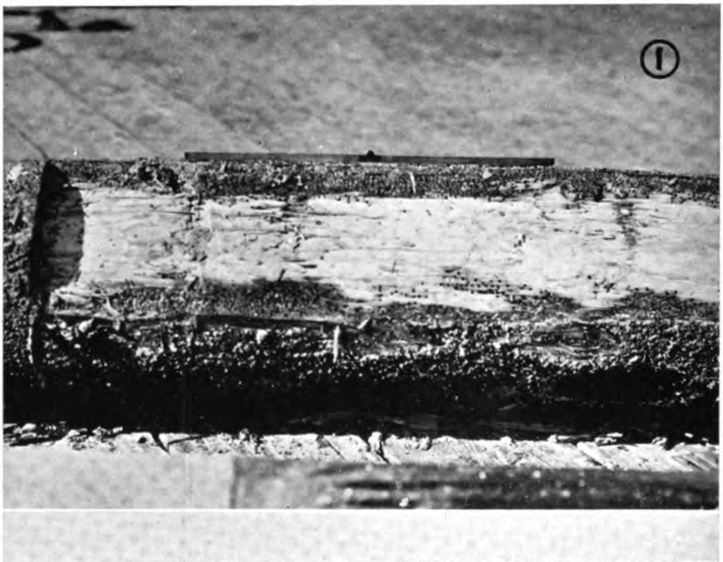


PLATE 21

Breaking point of a 6 by 8 Douglas fir test timber planted July 1, 1920, at Southern Pacific wharf, Port Costa, California, in 15 feet of water. Removed December 8, 1920, breaking 3½ feet above mud-line. *Teredo navalis* in place in burrows.



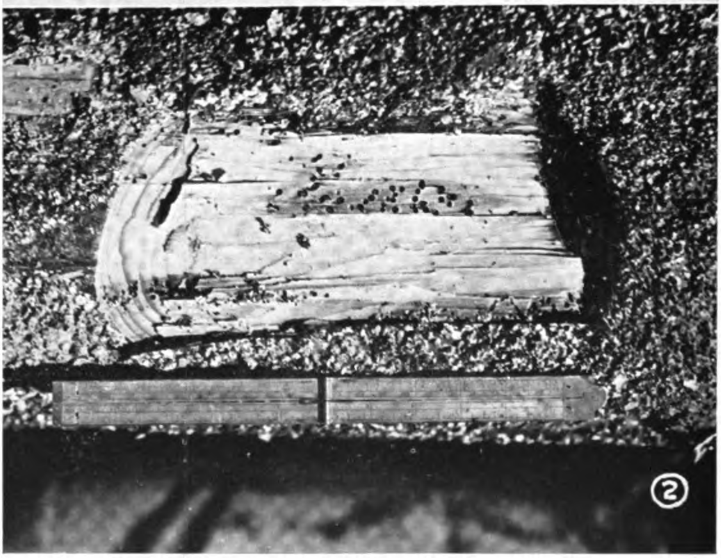
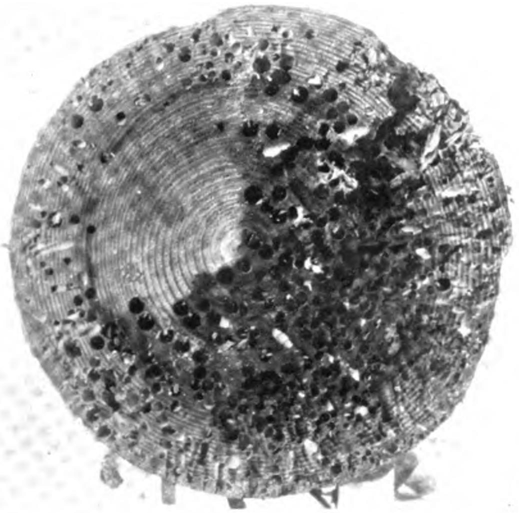


PLATE 22

Fig. 1. Green Douglas fir pile driven without previous exposure to sea water, August 14, 1920, at Mare Island Navy Yard, California, pulled October 18, 1920, showing 2½-inch penetration by *Teredo navalis*.

Fig. 2. A similar pile coated with solid asphalt, grade D, applied hot, showing 2-inch penetration by *Teredo*.



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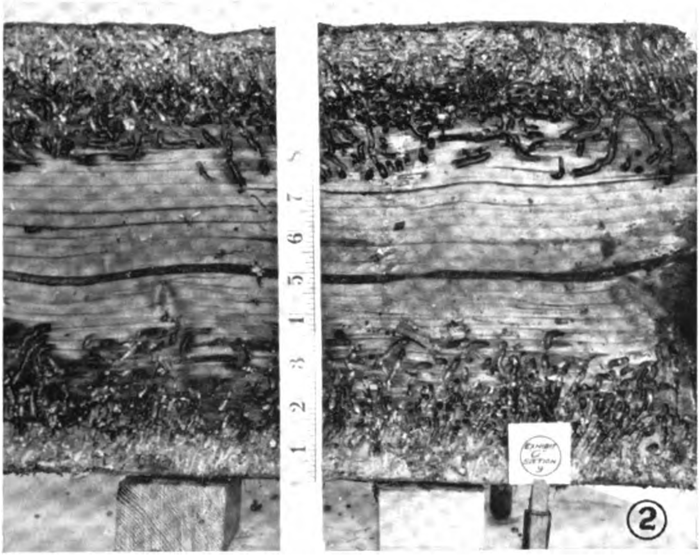
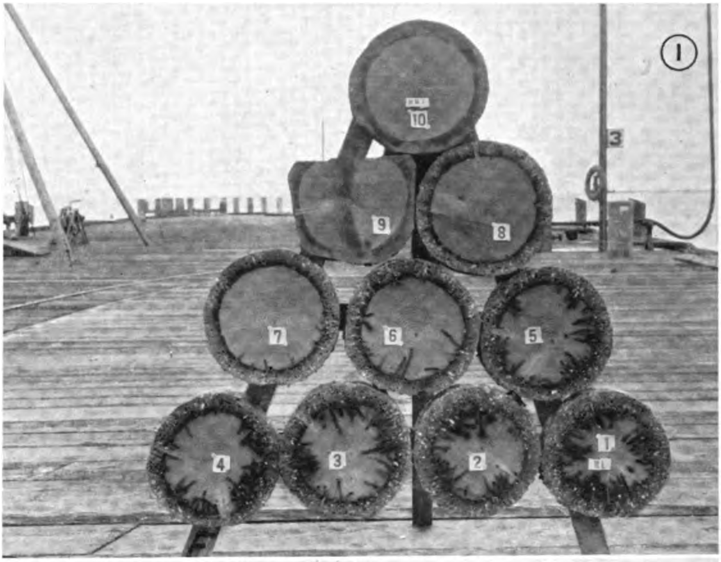


②

PLATE 23

Fig. 1. Cross section of Douglas fir pile from Station 6000, Dike 12, Mare Island, pulled April, 1920, showing ravages of *Teredo navalis* superposed on the larger burrows of *Xylotrya.*

Fig. 2. Green Douglas fir pile driven at Mooring Z, Mare Island, August 14, 1920, and pulled December, 1920, showing 4-inch penetration by *Teredo navalis.*



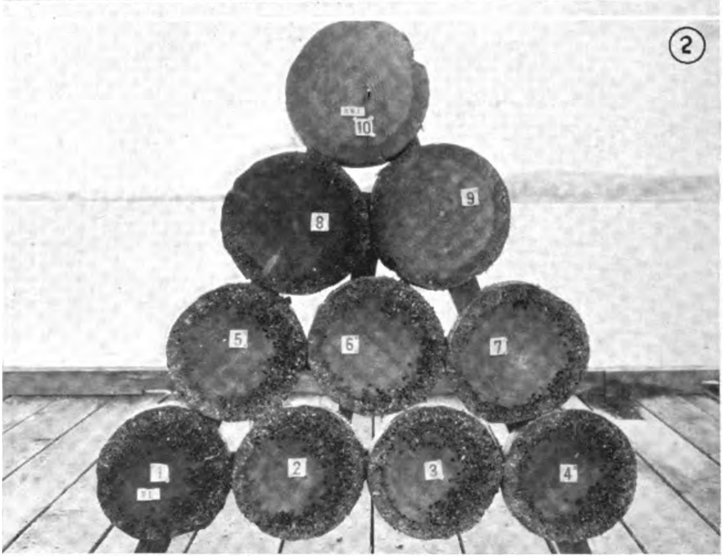
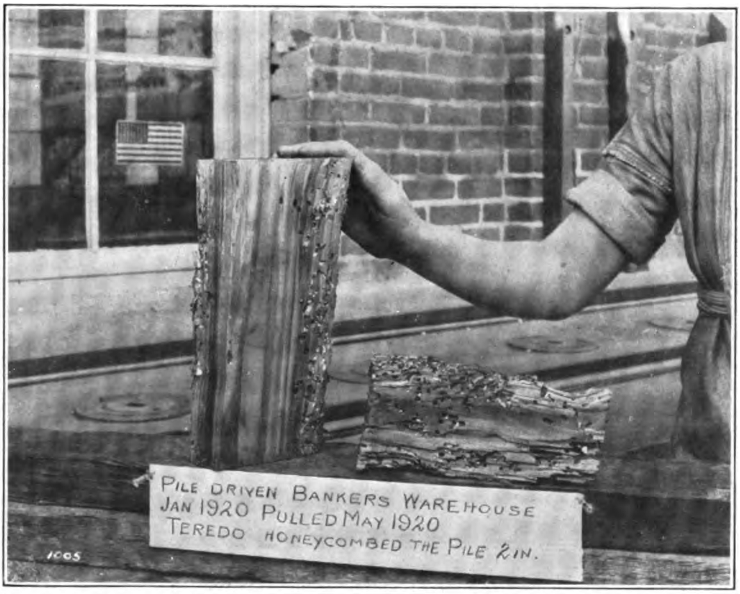


PLATE 24

Fig. 1. Fender pile of Douglas fir from wharf of Shell Oil Co., Martinez, California, pulled November 5, 1920, showing penetration of *Teredo navalis* in 1920(?) at ten equidistant sections. Distance from mud line to high water, 29 feet.

Fig. 2. Brace pile from same in 26 feet of water. Downstream exposure at left.


PILE DRIVEN BANKERS WAREHOUSE
JAN 1920 PULLED MAY 1920
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1005

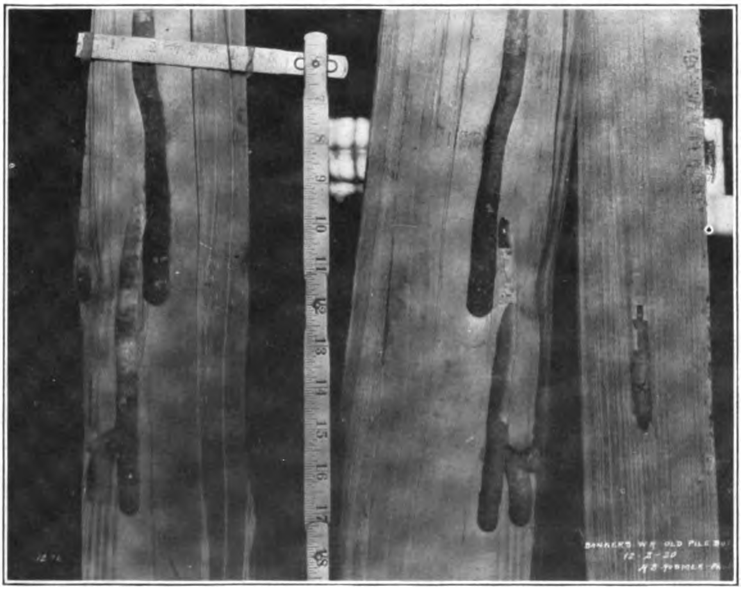


PLATE 25

Fig. 1. Douglas fir pile driven January, 1920, pulled May, 1920, at California-Hawaiian Sugar Refinery, Crockett, California, showing 2-inch penetration by *Teredo navalis* in 3½ months or less. Breeding season therefore apparently begins not later than late in March.

Fig. 2. Old piling at Banker's Warehouse at Crockett, showing burrows of *Xylotrya setacea* and attack of *Teredo navalis* (at right). Pulled December 2, 1920.

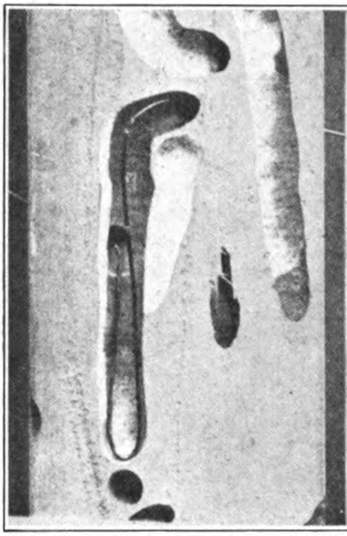


Fig. 1

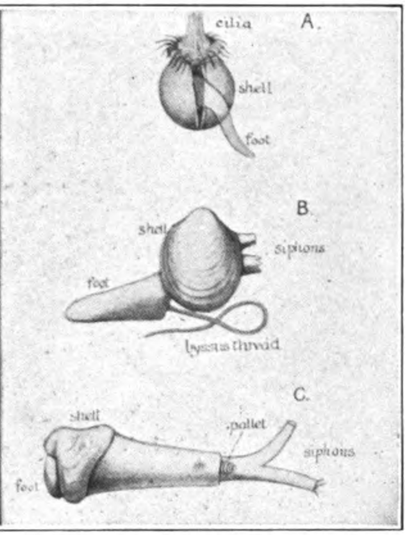


Fig. 2

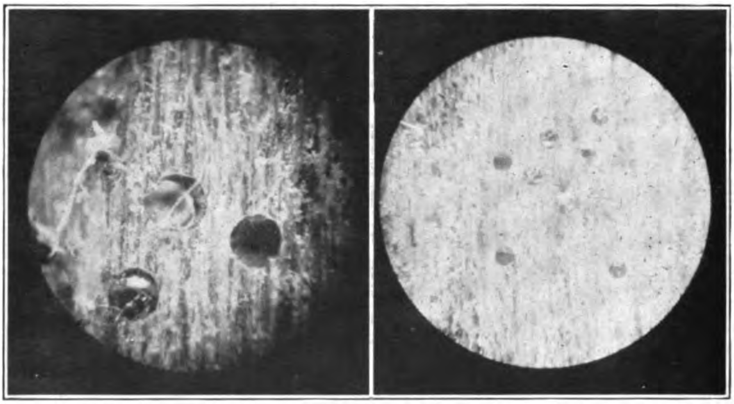


Fig. 3

PLATE 26

Fig. 1. Burrows of a shipworm. A wire passed into one of the burrows showing a change of direction on approaching a neighboring burrow. After Calman (1919).

Fig. 2. Stages in development of the shipworms. A, Free-swimming or larval stage. B, Creeping stage after settling on surface of wood. C, Stage shortly after beginning to burrow. (A, *Teredo,* after Quatrefages. B and C, *Xylotrya,* after Sigerfoos. All much enlarged.) From Calman (1919).

Fig. 3. Initial attack of larval stages of *Teredo navalis* on experimental piling planted July 1, 1920, at Southern Pacific wharf, Port Costa, examined August 4, 1920, magnified 10 and 24 diameters.

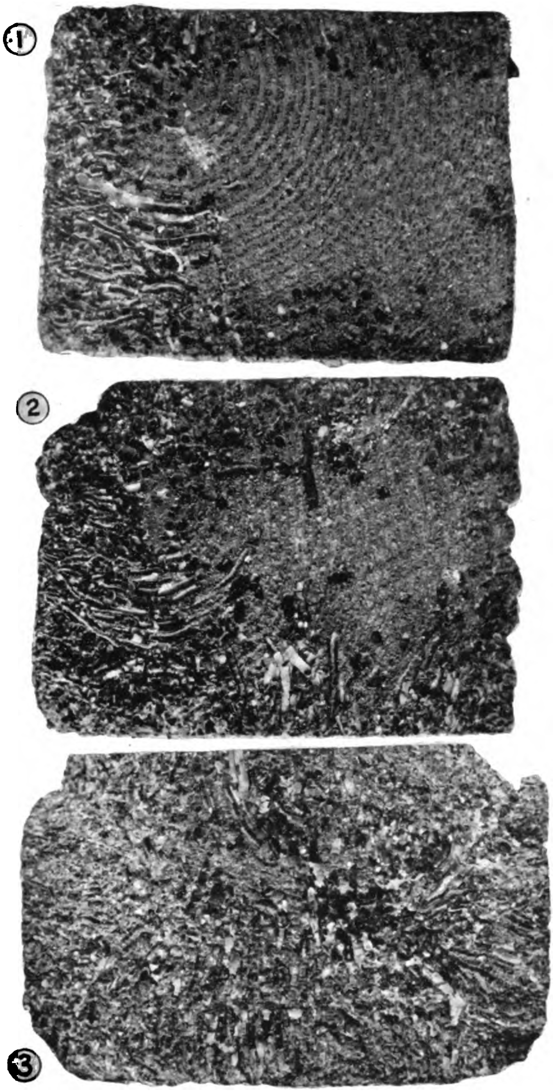


PLATE 27

Destructive action of *Teredo navalis* on a Douglas fir 6 by 8 timber planted at Southern Pacific wharf, Port Costa, California, July 1, 1920. First larvae detected on August 4th. Timber removed December 8th, 1920.

Fig. 1. Section 10 feet 2 inches above mud-line.
Fig. 2. Section 6 feet 6 inches above mud-line.
Fig. 3. Section 6 inches above mud-line.

Note contrast between inshore (right) and offshore (left) sides in the intensity of attack and destruction.

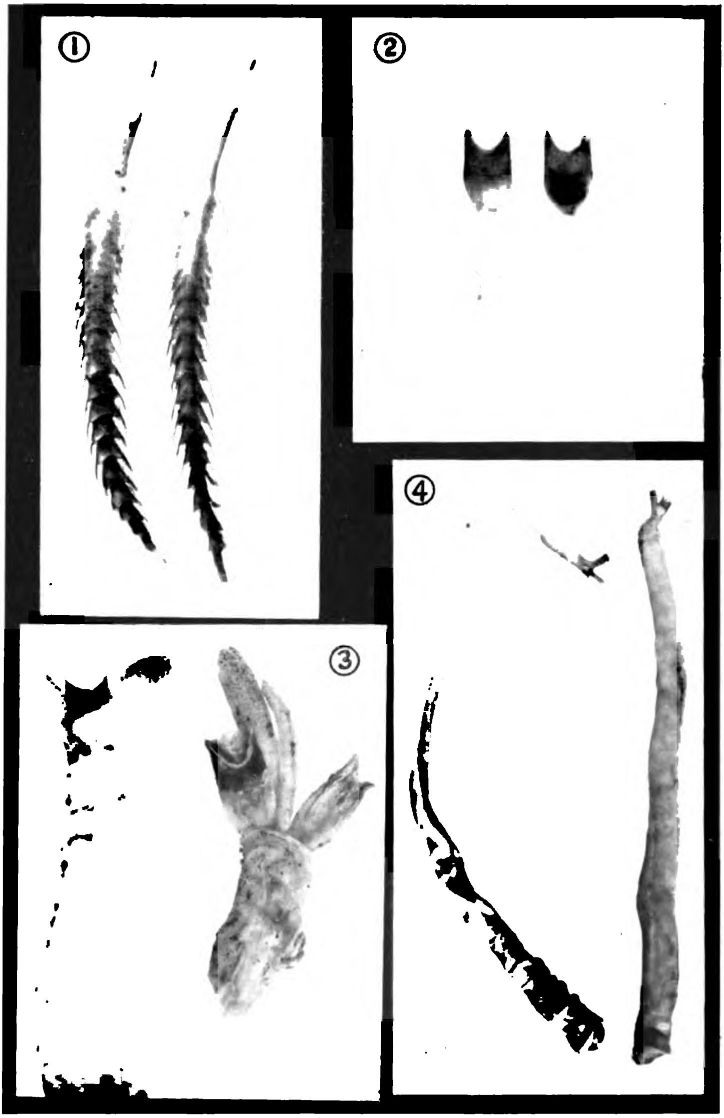
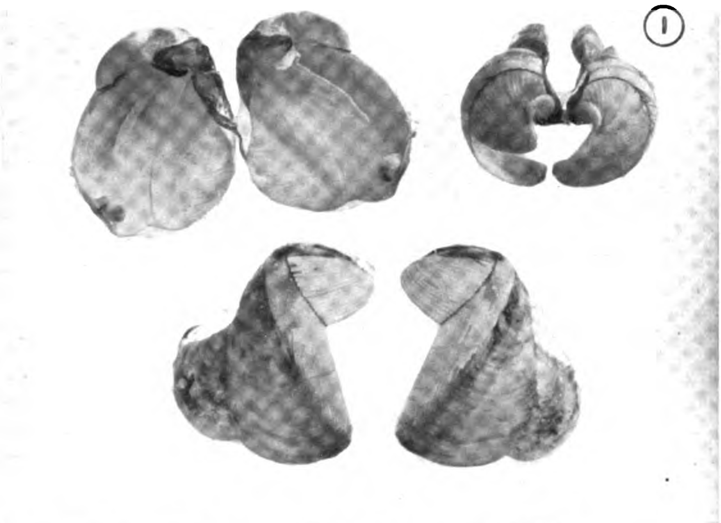


PLATE 28

Fig. 1. Pallets of *Xylotrya setacea.* Natural size.

Figs. 2–4. *Teredo navalis* from Port Costa. Fig. 2, Pallets, enlarged. Fig. 3, posterior end showing pallets and siphons, enlarged. Fig. 4, entire animal, two-thirds natural size.



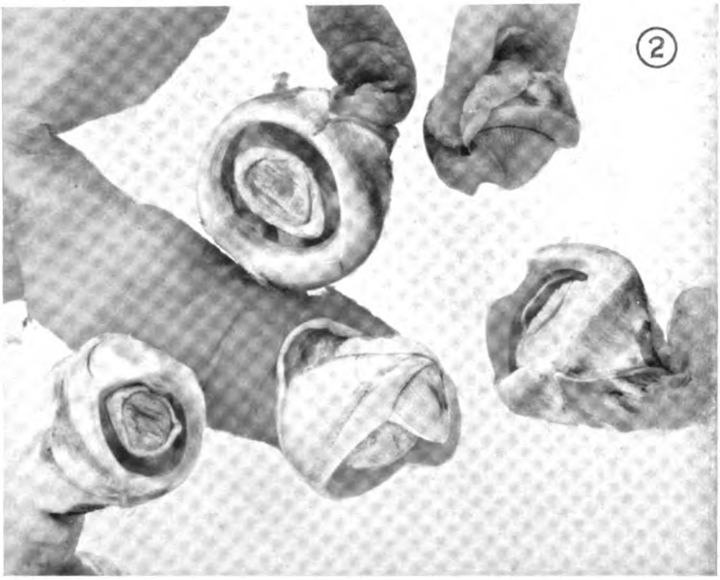


PLATE 29

Fig. 1. Shells of *Teredo navalis.*

Fig. 2. Anterior or head end of *Teredo navalis,* showing shell, centrally located foot. Enlarged about 5 diameters.

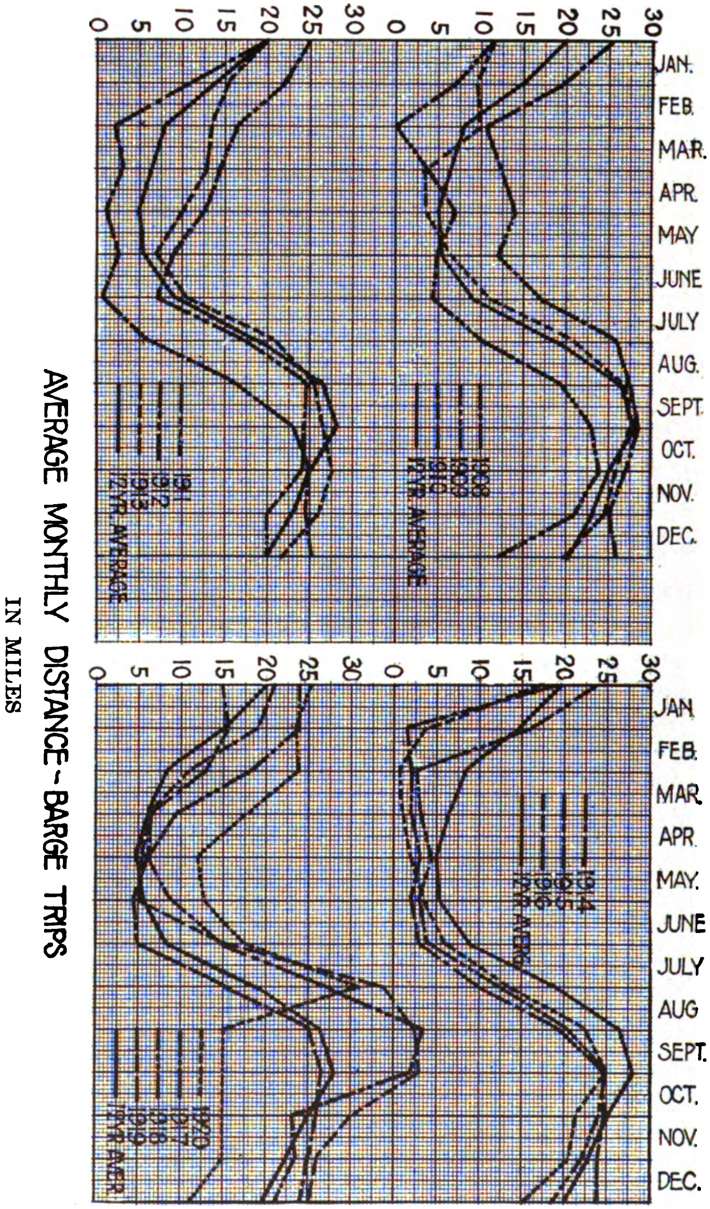


PLATE 30

Graphs of average number of miles per trip upstream of water barges of California-Hawaiian Sugar Refinery at Crockett, California, 1908–1920. Sudden change in August, 1920, due to change in source.

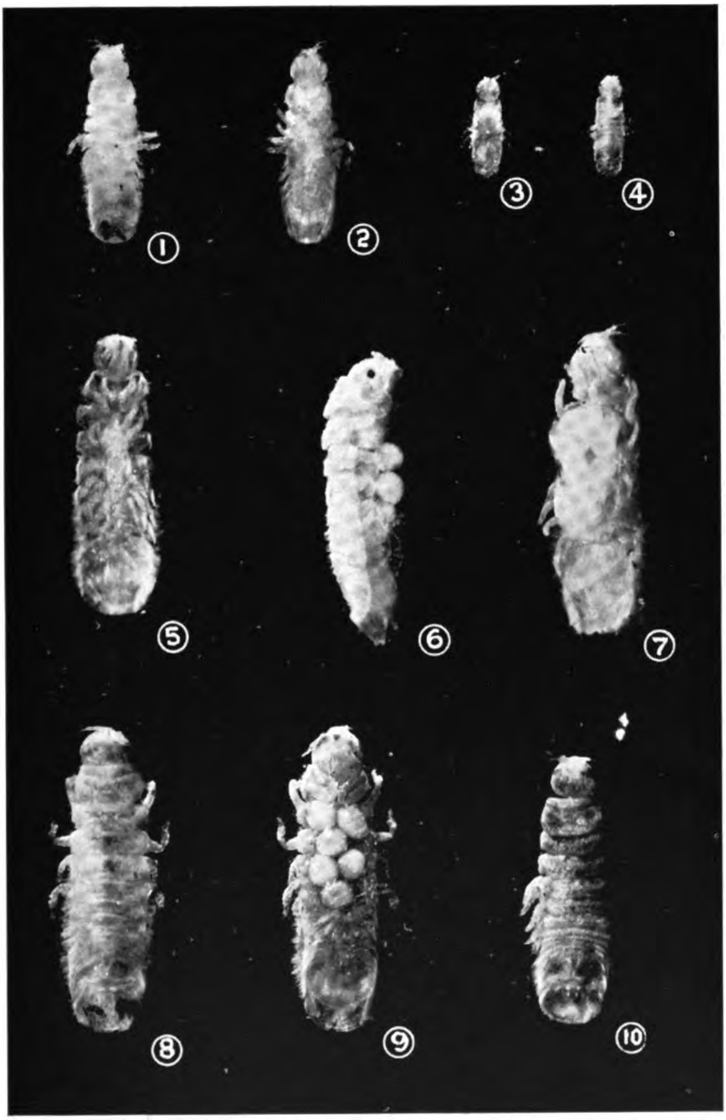


PLATE 31

Limnoria lignorum (Rathke)

Figs. 1–4. Young stages.
Figs. 6, 7 and 9. Females with eggs.
Magnified 11 diameters.

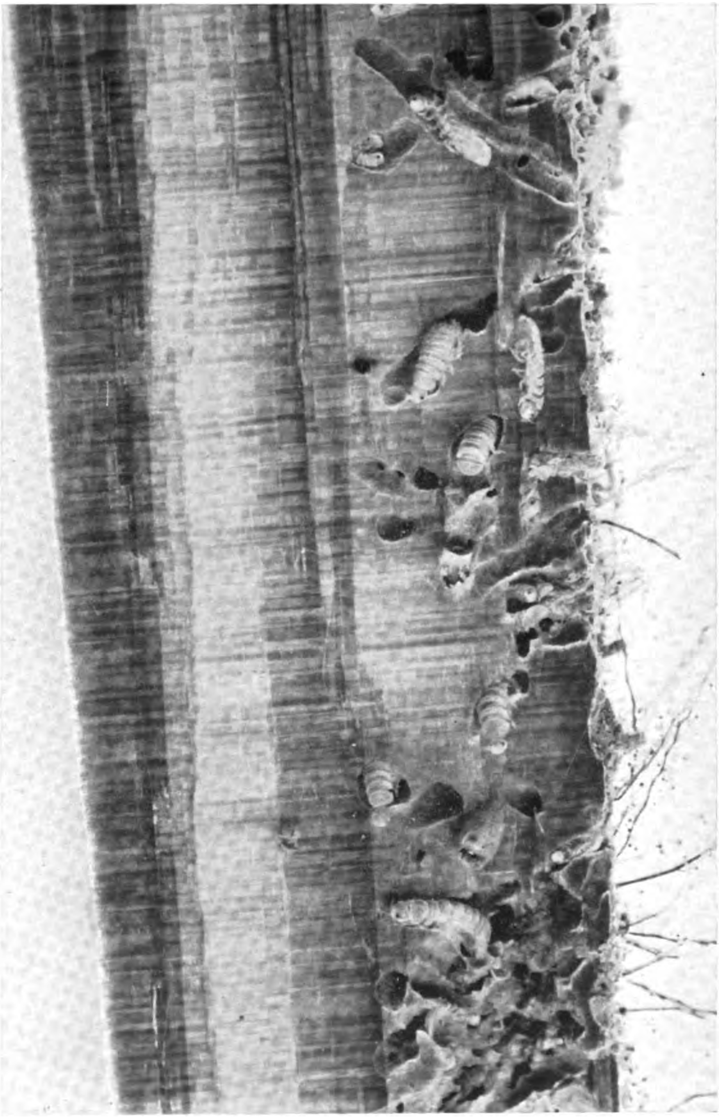


PLATE 32

Limnoria in place attacking wood. Hydroids on the outer surface (right). Magnified 5 diameters.

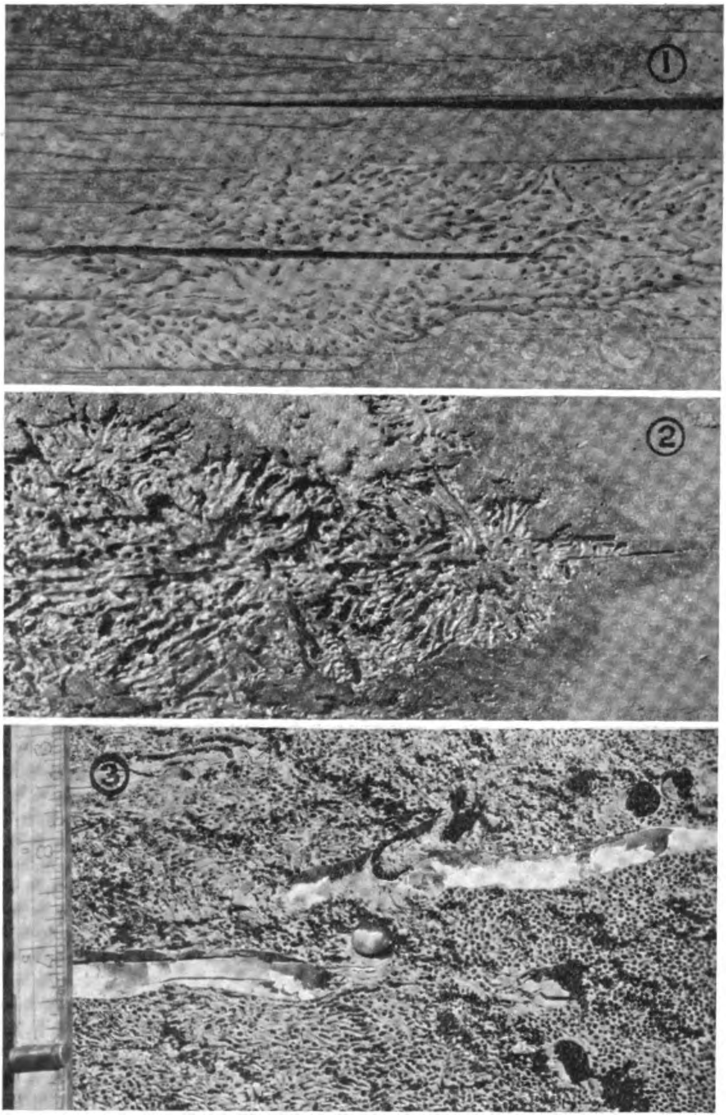
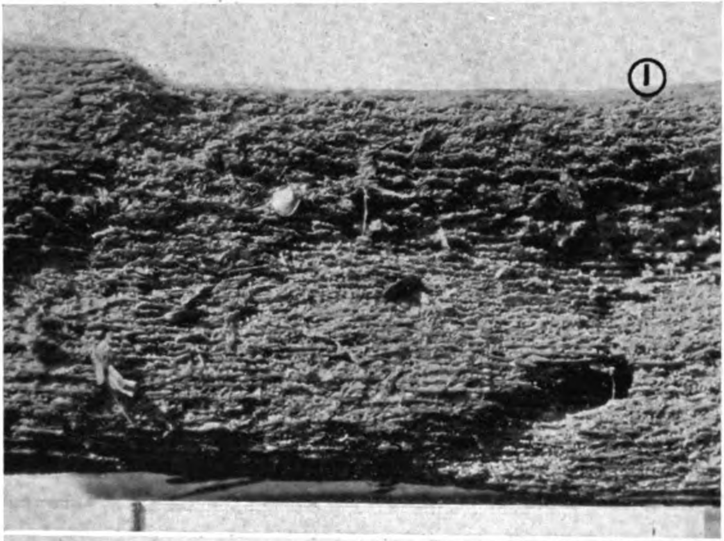


PLATE 33

Fig. 1. Untreated Oregon fir fender pile one month, July, 1920, in Municipal Quay, Oakland Estuary. Initial attack of *Limnoria*. Natural size.

Fig. 2. Untreated Oregon fir pile in Southern Pacific Oakland Mole. Deeper penetration by *Limnoria*.

Fig. 3. Untreated Oregon fir fender pile, Oakland Municipal Quay, driven 1913, removed 1920. *Limnoria* attack uncovering *Xylotrya* tubes.



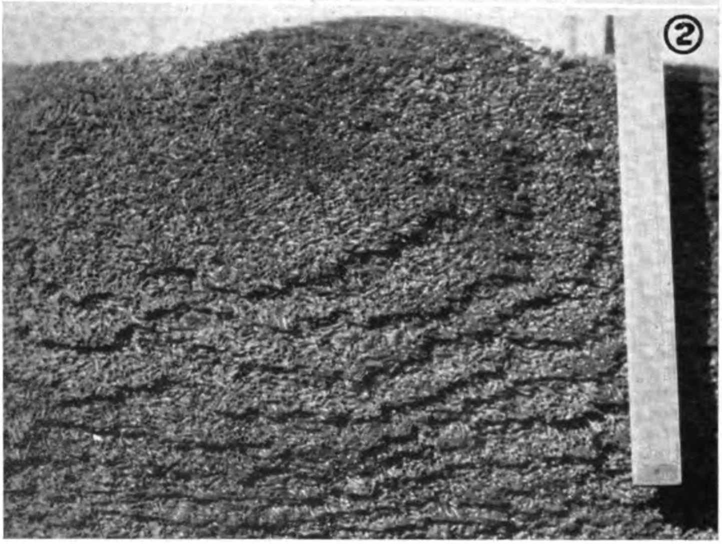


PLATE 34

Fig. 1. Untreated square Oregon fir timber, San Francisco, Pier 7, November 3, 1920. Radial surface showing erosion by *Limnoria* between the harder part of the annual rings. One-fourth natural size.

Fig. 2. Tangential face of the same timber.

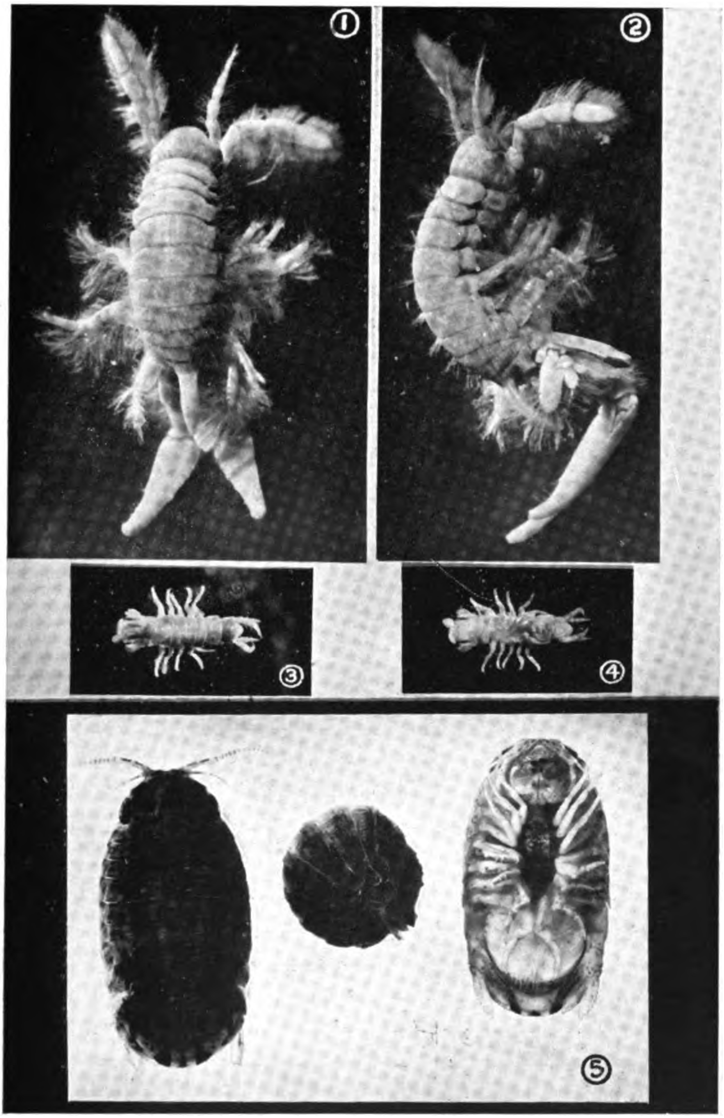


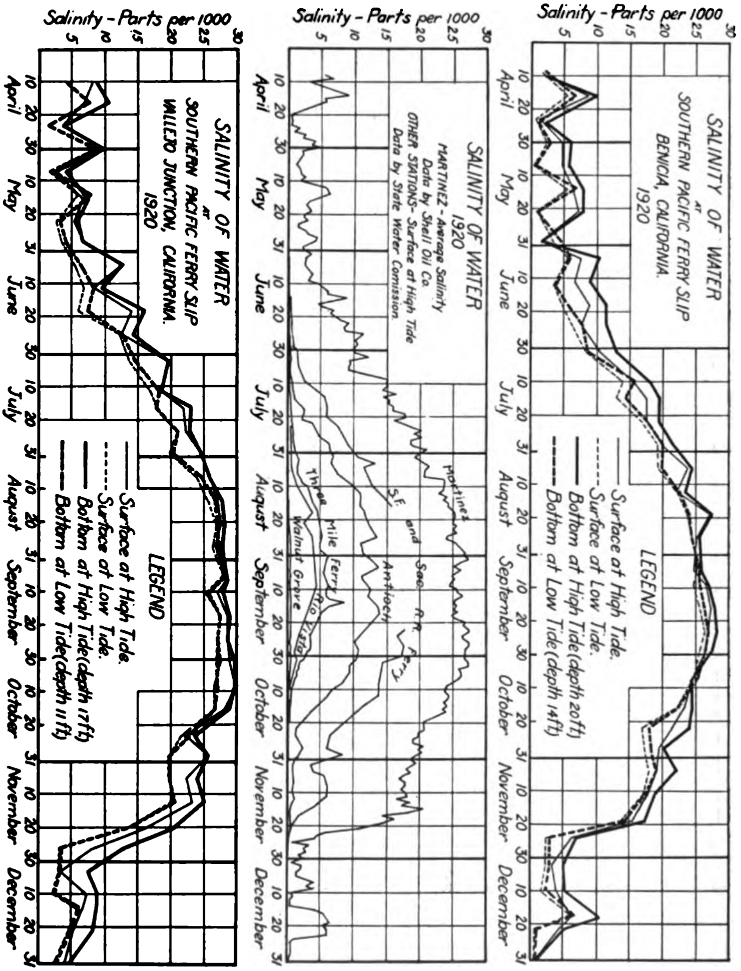
PLATE 35

Fig. 1. *Chelura terebrans*, male, from Charleston, S. C., dorsal view. × 11.

Fig. 2. Lateral view of same. × 11.

Figs. 3 and 4. Dorsal and ventral views of female *Chelura*. × 5.

Fig. 5. Dorsal, lateral, and ventral view of *Sphaeroma pentodon* Richardson.



Salinity graphs.

PLATE 36

SUPPLEMENTARY REPORT

FACTORS CONTROLLING THE DISTRIBUTION AND RAVAGES OF THE MARINE BORERS

By Charles A. Kofoid*

Man's control of nature is the function of his scientific knowledge of the forces and factors operating in the domain he seeks to control and of his freedom from superstition and scientific error. His knowledge operates quantitatively only insofar as his breadth may increase the opportunities for him to apply particular factors, that is, qualitative elements, from his domain of science to particular problems which ceaselessly arise in the realm of the control which he is endeavoring to expand. Hence, the futility and folly of every attempt, in theory or practice, to separate the so-called pure and applied sciences. Pure science of yesterday often becomes the applied science of today and becomes available solely because it was sought without anticipation of its application.

The story is told of an eminent mathematician who thanked God that he had completed an elaborate formula of which no one could ever make any use. This formula is today an essential factor in the equipment of the electrical engineer.

Biologists are today experimenting with the effects of the ductless glands on the legs, the color, and the sexual activities of frogs and salamanders. Their work may unlock the secrets of the control of some human deficiencies and even come near to the secret of the fountain of eternal youth.

The recognition of the value to a democracy of the expert unattached to commercial enterprise, and, therefore, presumably capable of an unbiased judgment, is becoming increasingly important as the democratic movement in world politics progresses. With the rewards available under the present industrial regimé, it becomes increasingly necessary to attract to the field of pure science men of the initiative, energy, enthusiasm which modern business demands of its devotees. To this end, it is essential that the social rewards, both in standing in the community and recognition of his values should be adequate and certain. It is, indeed, in the interests of industry itself that this should be widely recognized.

It is well-known in the chemical field that the German dye industry was content to invest its resources in a large and efficient staff of chemical experts whose sole duty was the exploration of possible resources of coal-tar products. Not a few high-salaried men worked years in this industry without a single result of their work entering the commercial field, but this method gave Germany the mastery of the dye industry, and the failure to observe it robbed Great Britain of her initial control thereof.

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*Professor of Zoology, Assistant Director Scripps Institute for Biological Research, University of California, Berkeley, California.

A few years ago, one of our leading American railways which stores its idle freight cars in midsummer on prairie sidings in Illinois, found that the air brakes of these cars were invariably out of order when returned to service and the wandering hobo who made the cars his temporary tenement was charged with having maliciously plugged the air vent with mud. The problem was not solved, however, until a university specialist in wasps determined the diameter of the mud dauber's head and it was thus possible to preclude his use of the air-brake as a storage house for stupefied spiders on which he was feeding his larval family.

Qualitatively important factors necessary to solve industrial problems can be most certainly found when the pure sciences dispassionately and without prejudice of interest put all the cards on the table. The more practical, as ordinarily understood, is, in the long run, in reality, the least practical course.

It is fortunate, indeed, for both the pure and applied sciences that engineers, whose training and interests overlap both fields, are in a particularly fortunate position to bring to the attention of the industrial agencies with which they are associated the importance of the pure sciences in education, in research, and to industry.

The attack on the problems of marine borers in piling affords a happy instance of the intertwined relations of various sciences with one practical industrial problem, and of the interlacing of the so-called pure and applied aspects of these sciences. For the solution of the problems of the ultimate adequate control of these borers, it is the work of the oceanographer to unravel the play of currents and salinities, of the physical chemist to determine the hydrogen ion concentration, of the biologist chemist to determine the lethol elements in tar acids and creosote, of the engineering chemist to devise methods of preserving these at their highest efficiency for the longest time in submerged wood, of the biologist to determine not only the nature and distribution of the borers but their life histories, including the rate of development, modes of dispersal, methods of attack, tropic reactions to protective substances employed, and the environmental factors which control, limit or modify the distribution and ravages of these enemies of industry.

Civilized man, because of his expanding control over nature, is ever the disturbing factor in what biologists are wont to term the balance of nature, which is that adjustment of living organisms to their environment which gives stability and continuity to the life in any locality. When any factor of this organic equilibrium is moved, all others readjust to meet the change. Hence, prairie and forest, river, bay and even the inlets of the ocean itself are now and again transformed in their fauna and flora by man's control. The bison gives way to the Hereford and the lupine to alfalfa.

Man's seafaring habits create huge cities with their sewage and industrial wastes at all great inlets and estuaries of the ocean. He transplants trees of the forests into the sea for his wharves and docks. By his wooden ships and lumber industry together with the garbage and wastes of his cities he vastly increases the amounts of wood exposed to salt-water in these localities. By the movement of his ships with their circulation systems and tanks full of sea-water charged with the larval stages of the marine fauna of distant ports he creates and maintains new channels for distribution and interchanging of old faunas. Since the days of Raleigh and Columbus, of Drake and Cook, he has been establishing in every great seaport a fauna as cosmopolitan as his shipping and trade routes. Thus every great seaport is a center of faunistic influence spreading to every other port with which it has maritime connections. Every bit of wood exposed to sea-water in our merchant ships, and every nook and cranny of the pipe of the circulation system of a great trans-oceanic steamer is a refuge for many a home-seeking immigrant which may people distant seas and harbors with its kind. Thus the widening circles of a marine catastrophe, such as that which has taken place in San Francisco Bay in the last year, will sooner or later lap the shores of many a distant port.

Nature teems with life. Every available shelter affords a home for some organism which is subtly adapted to that particular type of environment. This is especially true of the sea with its pelagic life at all levels adapted to changing illumination and pressure, its abyssal fauna living in eternal darkness and in a temperature but little above freezing, and its littoral fauna living in the dashing breakers of the coast. This littoral fauna has been a great area of evolution of animal life. It is the region of greatest diversity of environmental factors, and in consequence, of the widest amplitude of adaptability on the part of its constituent fauna to the widest range of environmental influence, such as a movement of the water, changing and shifting bottom, varying chemical conditions, including that of salinity, and rapidly repeated temperature changes which accompany the phenomena of tides. It is preeminently the home of plastic, readily adaptable organisms. A group of marine borers is included in this plastic association.

Our great harbors, with few exceptions, are estuaries of the sea, receiving streams and having fresh-water, brackish-water, and salt-water areas which shift with the tides, and are subject to flood and other conditions attendant on rainfall and run-off of the tributary territory. They have, therefore, in the past been the recipients of driftwood from floods, and, long before man sailed the seas in his wooden ships, they were the homes of the marine borers who appropriated this wood as a shelter and refuge. They have adapted themselves to the changeable environment in which this shelter is found, an environment of change in salinity, temperature, chemical conditions and food supply, and have adapted themselves to an environmental amplitude which is the greatest in the whole world of marine life. Their life in this changeable environment has endowed the marine borers with a high degree of adaptability to extremes of temperature, tidal exposure, salinity, chemical constitution of the water, now represented by sewage and industrial wastes, to varying and intermitting food supply and to other marine hazards.

This wide range of adaptability and the high degree of resistance to adverse conditions, as compared with organisms of the open sea, facilitates in many ways the dispersal of the marine borers and also their attacks upon different woods and their ability to penetrate some forms of protection and to enter even some timbers which have undergone protective treatment. It is also a factor involved in their ability to rapidly and effectively occupy a new territory whenever such is open to their invasion.

Prime factors affecting the growth and distribution of all life are food, shelter, and temperature. In marine environment, there are added to this or combined with them as subsidiary factors, salinity, temperature amplitude, current, depth, nature of the wood invaded, sewage and industrial wastes, the tropisms of the larval stages, and reproductive habits and seasons. These combine in ever varying permutations and intensities, and in changing seasons and changing thresholds, to form a complex not readily unravelled with accuracy, even when one factor predominates, as in the case of the invasion of flood waters.

The food of the marine borers differs in the two classes of molluscs and crustaceans. The former, teredo and xylotrya, are close relatives of the oyster and the clam, and are not structurally worms, though called ship-worms, because of their worm-like shape. They are, in reality, bivalved molluscs, with the shell, foot, mantle, gills and siphons characteristic of the lamellibranch molluscs such as the clam. They have likewise the same feeding habits as the clam and oyster. By means of the cilia, or microscopic whips which cover the gills and tracts on the surface of the mantle which lead towards the mouth, they create an incurrent flow of water from the pin-hole on the surface of the pile into the long ventral siphon and thence into the mantle cavity. The lines of cilia in the surface of this cavity pick up the microscopic floating algæ, diatoms and animalcules out of the incurrent water and entangle them in mucus threads and pass them into the mouth at the anterior end of the animal at the inner end of the burrow where 2 mobile flaps assist in carrying the food into the mouth. These boring molluscs are, therefore, wholly dependent upon the food which passes the orifice of their sheltering burrow. Anything which limits the amount of this food, or the rate at which it passes the burrow, reduces their rate of growth, and whatever increases the food in amount or rate of movement, accelerates their activities and their rate of growth and reproduction.

The molluscs are dependent on this incurrent flow of the passing current, not only for their food, but also for their respiration, carried on by their elaborately formed gills. Stoppage of the circulation of the water in and out the mantle cavity will slow down their activities, and eventually when the oxygen of the imprisoned water is exhausted will asphyxiate them. Growing barnacles, as their base spreads, often cover the breathing and feeding orifice of the underlying teredo, and thus destroy the borer by asphyxiation.

The overgrowth of marine organisms which also feed on the plankton may so starve out teredo as to hinder its growth. The pumping apparatus of teredo, though extraordinarily simple, is, however, sufficient to maintain a current, even under very adverse circumstances. From this fact in the physiology of these borers, it is evident that any system of extermination which effectively closes the outlets of the burrowing teredo will destroy it sooner or later. It is well-known that oysters may be shipped for weeks at low temperatures in living conditions without access to sea-water, by reducing their physical activities and demands on oxygen to a minimum. In like manner, teredo can survive possibly for several weeks after closure of its orifice or cessation of circulation of the water.

The ocean, in common with lakes and rivers, produces each year crops, or rather a continual succession of crops of microscopic food supply known as plankton or the ocean meadows, whose tonnage per acre is comparable in weight and chemical composition to the forage crops of wild or cultivated land. The marine borers feed upon this exclusively, appropriating it as it passes their door. They never go foraging, except in the case of the free-swimming larvæ. This food supply is not equal in abundance or quality at all times or in all places. In ocean meadows, it runs a seasonal course, not unlike that of the land. It has a spring and autumnal flush of growth and a midwinter period of depression. Other things being equal, the spring and early summer and the autumn are periods of most abundant food, and, therefore, the periods of reproduction and growth of the borers. There is, however, a sufficient amount of such food present at all seasons and in most localities to provide for the maintenance and for some growth of the borers.

Differences in the effectiveness of their invasion and the consequent industrial menace in different localities, and their varying rate of growth in different seasons, are directly attributable, inside the zone of favoring salinity, to variations of the food factor.

The local distribution of the food supply of these borers varies greatly according to salinity, depth, and varying chemical constitution of the sea-water. Thus the brackish-water zone of rapid changes between invading fresh-waters and tidal ocean-waters is an impoverished area in which fresh-water species entering with the river waters are quickly destroyed and the marine species of the plankton entering with the tidal currents likewise perish. There are only relatively a very few species which survive the extremes of salinities and the abrupt admixture of fresh and salt-water in rapidly changing tidal areas. On the other hand, waters of slightly reduced salinities, covering large areas of tidal flats or shallow regions, and relatively slow tidal admixtures, such as with the oyster flats of the Chesapeake Bay and the Gulf Coast, produce a great abundance of plankton, especially favorable to the growth of the oyster and presumably also for teredo. Extension of salt-water into Suisun Bay and the extensive channels above it afford an ideal condition for the development of the food supply especially favorable for the growth of teredo in Carquinez Straits and in adjacent territory.

Plankton is subject to vertical migration in response to the changing diurnal rhythm of illumination and changing viscosity of the water with changing temperatures. This viscosity, or the capacity for flotation, doubles with a drop of 10° C. in temperature. This affects the flotation upon the larval stages as well as the food supply of the adults. In consequence of the combined action of these two factors, the uppermost meter of water, which is best illuminated and warmest, is less densely inhabited by plankton than the deeper layers, and, as a consequence, we find that, as a rule, marine borers settle less abundantly nearer the surface than at deeper levels. The exposure to air between the tidal levels cooperates with these factors to reduce infection and growth in this region, but permits it to extend above the mean tidal level, usually about 6 inches below the barnacle line. The limiting factor here is the submergence for a long enough time during the median and highest tides of the month for an adequate feeding period. The uppermost level to which teredo can go is thus influenced by the amount of food and the period of exposure to the air. As such elements are variable, this level will vary in different localities. Since the same factors affect the food of the barnacles, we find that 6 inches below the barnacle line is a fair guide to the level at which molluscan borers may be expected to occur. Teredo tend to go to higher levels than xylotrya.

Conditions of the sea-water also profoundly affect the volume of the food supply, and probably influence the degree of settlement of the larvæ upon marine structures. The sea derives its fertilizing constituents from the nitrogen-rich wastes of the abyssal depths, which in solution wells up against the western shores of all continents, owing to the rotation of the earth. This is responsible for the rich fisheries on these coasts, and ultimately affects also the rate of growth of marine borers in these localities.

The ocean also receives fertilization from the continental wash and wastes of cities in an irregular and local distribution. Sewage fertilizes harbor waters and increases the plankton products. It is deleterious only when by decay it robs the sea-water of all dissolved oxygen for a period of time sufficient to asphyxiate borers. These borers, therefore, thrive near sewers, provided there is a sufficient daily exposure to aerated sea-water. Sewage kills them off, or prevents their invasion, only when currents are so sluggish and the concentration so great that the region is one of almost continual ferment and decay most of the time. Thus the xylotrya was found thriving in San Francisco Bay water, at the mouths of large sewers at Hunter's Point, and teredo navalis occurred in the mouth of the sewer at Pinole in the timbers enclosing the sewer outlet. The salt-water of these localities was sufficient to permit adequate respiration by the borers in the presence of the sewage some of the time. They would be unable to exist where putrefaction prevails, as shown by continual gas formation, blackened sludge and foul odors which obviously define areas of putrefaction.

Other factors which affect the amount of the plankton are minute traces of certain chemicals. Copper is deleterious in the minutest doses to the plants of the plankton. One part of copper sulphate to ten million by weight will completely exterminate many species, and copper chloride is even more toxic. On the other hand, minute doses of arsenic and iodine stimulate growth. The ever-changing wastes of a metropolis thus add greatly to these chemical factors. Tidal currents and chemical reactions within the sea confuse, dilute and obscure them. In a general way, however, many investigations have shown that the food supply generally available in the plankton is above the minimum necessary to support the life dependent upon it, and engineers may expect to find that above the fresh-water dead-line, about 8 to 10 parts per 1,000, harbor waters give enough food at all times to keep teredo navalis going, and to make it a menace to marine structures.

There are several physical factors which affect the food supply available for teredo, and thus determine the rate of the destruction of the pile. Most evident is the rate of the movement of the tide or other current past the inlet of teredo. As a general rule, tidal currents of a high velocity or of more recent oceanic origin are higher in salinity and plankton content than in the upper reaches of the more slowly moving tidal currents. Therefore, those marine structures near the inlets of harbors stand in greater danger, other things being equal, than those more remote from the sea. But, whatever the plankton content of the current, the fact is that the food supply available at the inlet of the teredo is a prime factor in its rate of growth.

In slack water currents, the amount of water which must be sifted per unit of food supply is greatly increased and the rate of growth accordingly depressed. Hence marine structures exposed in straits or narrows where constriction speeds up the rate of flow past the piling are in a location of hazard increasing proportionately with the increased rate of flow. However, there comes a point in many localities in which any increase in food, or the rate of flow, ceases to affect the rate of growth, because the maximum level of utilization has been passed.

It is this factor of available food supply which constitutes a hazard dependent upon the rate of the current which the engineer may well consider in all marine construction.

The food of the crustacean borers, unlike that of the molluscan ones, is not plankton. In the case of sphæroma, it is obtained by foraging in the neighborhood, while both limnoria and chelura also eat the wood, or at least pass it through their digestive tracts. They are, therefore, less dependent upon the movement of water about them. However, the rate of movement and the plankton content of the water influence the amount of marine growth on which these crustacean borers are in part dependent for food and thus indirectly become factors in the prosperity or adversity of these pests. For this reason, limnoria is very active in the narrows of the Golden Gate and near some sewers.

A factor of prime importance, and one on which we have as yet no specific information, but only inference by analogy from other organisms, is the group of tropisms or locomotor reactions of the larval stages to the physical and chemical features of the environment, such as gravity, light, salinity and other chemical conditions of the water. The larvæ of the borers may be expected to move towards or away from a pile, or in one direction or its opposite according to their sensitiveness to, and reactions to the prevalent form of physical or chemical stimulus.

It is not improbable that the protective feature of creosote rests upon the negative chemotropism of the larval stages of the borers to some repellent constituent of the creosote, and that these stages settle on the wood irregularly as they often do, because of their positive chemotropism to extractives of the wood which are more available at some places on the surface than at others. Experiments to determine the precise chemical nature of these repellents, the methods of increasing their amount, durability and effectiveness by controlled biological experiments are much needed.

The factors of acidity and alkalinity of the sea-water are of prime physical significance for the reactions of organisms in their movements and migrations and other operations of their bodily functions. This is most accurately measured by the so-called Ph. scale of the hydrogen ion concentration resulting from the electrolytic dissociation of substances in solution. Different species of animals are known to differ in their reactions to these factors of environment, but most marine animals find their optimum condition near the neutral zone of acidity-alkalinity. A rather wide range of adaptability to changing acidity on both the mollusc and crustacean borers is indicated by their wide range of distribution in water whose acidity varies greatly, as, for example, between pure oceanic waters and sewage-laden harbor water in which the process of decay greatly modifies this factor. The hydrogen ion concentration affects the union of the germ cells and the tropic reactions of the larval stages. It may thus limit and restrict seeding areas where all other factors favor their extension.

The temperature of the sea-water and of the air between tidal limits exercises a controlling influence upon distribution of marine organisms, and thus we find that species of Alaskan molluscs and worms found at tide levels in the North tend to keep to water of the same low degree, and, as they extend southward, they tend to sink to deeper and deeper levels. However, the marine borers, as a whole, have such a cosmopolitan distribution, from the equator almost to the Arctic Circle, and such a wide range of adaptiveness that the temperature changes in adjacent localities have little influence over their distribution. They do, however, set limits to the occurrence of particular species.

In a larger way, however, temperature changes and contrasts operate within a limited range to control all growth and to regulate reproduction. Thus a turtle's heart beats, a cricket chirps, and a parrot talks in accordance with Van Hoff's law that the velocity of chemical reaction is doubled with a rise of 10° C. Thus in the region of the temperature optimum for any vital phenomenon, a rise in temperature accelerates and a fall depresses the process. Other things being equal, teredo, xylotrya and limnoria do their destructive work more rapidly in summer and in warmer latitudes than in winter and in northern climates, but the optimum is not necessarily the same for any 2 of these species.

The reproductive processes and the life cycle of the marine borers play an efficient part in the rapid distribution and the full occupation of available wood for shelter and in the invasion of a new territory. It is unfortunate that as yet we have no adequate account of the life cycle and breeding habits of any of the marine borers. It is at best a fragmentary patchwork of data which we possess, and their limits and relationships are imperfectly known, and some of the published data are largely unsupported conjecture.

All the marine borers, insofar as is known, reproduce only by the sexual method. Parthenogenesis and a sexual division are unknown. Males and females occur in all species, but males appear to be less abundant, possibly because of their shorter life, or greater mortality. In all of the marine crustacean borers, limnoria, sphæroma and chelura, the number of young produced is small, the larvæ are not free-swimming, and are found in all stages of growth in close association with their parents in the burrow. They appear to be adapted to the boring habit soon after hatching. This absence of the free-swimming larval stage, with the small number, large size, and early efficiency of the young of the crustacean borers tends to intensify the local attack and to lower the birth rate in its susceptible early stages of distribution and infection.

It also tends to confine the attack to the parent locality, and to intensify it there. It also impedes the rate of dispersal into new timbers. It is only as the young or old borers inadvertently are caught out of the shelter of the burrow, are swept away by the current and gain a foothold on some timber that they invade new regions.

On the other hand, the presence of free-swimming larval stages in teredo and xylotrya, and their production in enormous numbers quickly distributes infection by them within the whole territory traversed by intermingling tidal currents which pass the infected piling. It was this fact of great numbers of free-swimming larval stages spread through the agency of tidal currents from the Mare

Island dikes and other infected timbers in the upper bay, to all other piling within reach of these currents, that accounts for the rapidity and destructiveness of the recent attack in Carquinez Straits.

By analogy from the numbers of eggs and larvæ produced by other molluscan borers, it is probable that the number of larvæ produced by one female teredo navalis may exceed 2,000,000. A heavily infected pile in 25 ft. of water may harbor in excess of 200,000 teredo. If one-half of these are male, there would still be produced in sufficient number of larvæ to seed heavily 500,000 piles by the teredo of this one pile, provided all the larvæ lived and got into some pile. This, of course, never happens. The death rate of the eggs and larvæ is very high, especially in the first few hours of life, and but a few of the migrating larvæ get a foothold on a pile. When they do settle down they find waiting for them a hungry horde of crustacean monsters waiting for a meal of teredo, and but a few of those which settle on the surface of the wood survive until they can dig in under cover. Still the surplus which nature provides made possible the complete occupation of available piling in Upper San Francisco Bay in the relatively short time of a single breeding season.

There is a significant difference in the breeding habits of teredo navalis and xylotrya setacea which has a bearing on the relative rate of infection and destruction of piling by these two species in San Francisco Bay. Teredo harbors its ova within its gills for the period of their early development. The sperm of the male cast free into the sea is drawn in by the siphons of the female and fertilizes the eggs. These develop rapidly into free-swimming larvæ and when able to care for themselves, to swim and feed, they are cast out into the passing current.

Xylotrya, on the other hand, casts out both the egg and sperm into the water. The 2 sex-cells must meet and unite within a few seconds, if at all, and the unprotected egg must pass its stage of greatest susceptibility to temperature changes, poisons, and enemies without the shelter of the parent's body.

It is a well-established biological fact that the death rate of organisms is highest in the earliest period of life. In teredo this period is passed in the shelter of the parent's body, while in xylotrya the young borers run all these risks in the open water with resultant higher death rate.

We find, therefore, in San Francisco Bay that the settlement of the larvæ of xylotrya on piling is relatively lighter than that of teredo, and that xylotrya which was not uncommon in San Francisco Bay, only got a slight foothold in the upper bay when salinities rose there, when teredo completely over-ran the territory. The difference in breeding habits is one of the prime causes tributary to this contrast in destructive efficiency.

Of all factors controlling the invasion of piling by the marine borers, none is more readily tested, more complicated in its behavior, or more potent in action, than the salinity of the water. It is this factor which maintains the impassable bar between the marine and fresh-water faunas. It limits the up-stream invasion of the marine borers, but does not stop them all at the same level. For example, sphæroma destructor of the Atlantic Coast does damage to piling in fresh water in St. John's River, Florida, as well as in brackish water. On the California Coast, sphæroma pentodon works in less salinities than the limnoria, and may be destructive, as on the Mare Island dikes, and at Antioch, before the other borers begin operations there. Sphæroma is a hardy animal, working effectively at higher tide levels and in lower salinities than the other borers.

On the other hand, limnoria and chelura are adapted to oceanic salinities and do their most effective work in water of normal salinity. They do not invade brackish waters very far. For example, in San Francisco Bay we have not found them above San Pablo Point, neither in San Pablo Bay nor Carquinez Straits.

The molluscan borers are peculiarly susceptible to salinity, because they continuously bathe their bodies in a stream of water brought in through the ventral siphon. Moreover, the lymph and serum of animal bodies generally is somewhat saline, thus resembling sea-water. The body of the molluscan borer when placed in fresh water absorbs an unusual amount of the fresh water just as oysters are "fattened" by exposure to fresh water. This interferes with their normal physiological processes and after a time death ensues. If, however, there is a tidal recurrence daily, or even fortnightly of a period of increased salinity, toredo can survive for a much longer time. For example, at Crockett, teredo navalis is still surviving (January 24, 1921) a salinity which has been much of the time below 10 parts per 1,000, since December 5, 1920, while at Martinez, they were all killed off early in January.

The lowest levels of salinity at which teredo navalis will survive in piling appear to lie between 7.5 and 10 parts per 1,000. The levels at which the larval stages will attack piling probably lie somewhat above this, perhaps between 10 and 15 parts per 1,000. We have not been able as yet to observe the settling process in a breeding season and correlate it with salinities; but last season's data of destruction suggest these limits as probable.

The limits of salinity, within which the different species of teredo thrive, vary greatly. A related borer, nausitoria dunlopi, lives in the River Como in India in fresh water. Teredo navalis, on the other hand, is a species adapted to life in brackish water, while the shipworm, teredo megotara, lives in timbers on the high seas.

Xylotrya setacea on our coasts lives in maximum salinities and has not been found to thrive in waters below 20 parts per 1,000.

In the case of marine structures, the engineer must, therefore, be on his guard to consider both the conditions of life, such as salinity, current, and food supply, and the particular organisms prevalent in the neighborhood. To this end, a regular system of periodical inspection of test-piling, and the identification of the particular borers found therein is advisable, and where investment and other conditions warrant, a systematic examination of and seasonal records of salinities should be kept. With these factors in mind, and individual and united effort to reduce the regions of infection, improve methods of protection and extend their use, it will become increasingly possible to conserve investments in wooden marine structures.

MR. F. D. MATTOS: Gentlemen, I desire to thank the contributors and the cooperators, as well as the members of my Committee for their hard work during this survey. [*Applause.*]

THE PRESIDENT: Gentlemen, the report is now open for discussion.

MR. J. H. WATERMAN: Mr. Chairman, I move that we recognize the work of this Committee and thank them for it. I think the body of men want to express themselves in appreciating the work that the Committee has done. [*Applause.*]

THE PRESIDENT: Might we have some discussion before we have a motion? We would like to call on Mr. Brown.

MR. A. A. BROWN: Mr. Chairman and Gentlemen: there are probably many of you gentlemen who have come here from the East and may not be altogether familiar with the great deal of attention that has been given to the Carquinez Straits district.

Carquinez Straits is located in Contra Costa County, which is the greatest industrial county in the State of California, probably the greatest industrial district on the Pacific Coast, and the south side of Carquinez Straits has the major portion of the industries in Contra Costa County.

I think there are probably quite a number of members here who are representing creosoting plants, and I have some data that I would like to give you on the comparison between the cost of driving creosoted piling as compared with concrete piling.

We have just finished driving some 3,000 creosoted piles, and approximately 500 concrete piles, ranging in length from 42 ft. to 105 feet. The creosoted piles, that is, the new ones we are purchasing, are costing an average of $1.12 a foot.

We found in driving the creosoted piles to refusal with a No. 1 Vulcan steam hammer that a considerable number of them were being shattered, so it became necessary to revise not only the driving specification but also the unit-load to be carried by the creosoted piling. We are now driving the creosoted piling with a No. 1 Vulcan steam hammer, obtaining a penetration of ¼ inch per blow, and using a unit-load of 20 tons per pile.

The concrete piles are driven with a No. 0 Vulcan steam hammer to a penetration of 6 blows to the inch, and loaded 35 tons per pile. These concrete piles cost $2.15 per lineal foot to make, and $2.80 per foot in place. Creosoted piling costs $1.30 per lineal foot driven, allowing for a very nominal breakage. From these prices and bearing values we find that the use of concrete piling costs approximately 25% more than creosoted, giving us what we believe to be a more permanent type of construction, and have every reason to believe the concrete piling will last for many, many years, having a much longer life than the creosoted piles, and there is no danger of the carpenter driving a nail or peavy into the concrete pile below the water-line. With reasonable care in handling and making we should get an almost unlimited life, so this is something, I believe, for the creosoting men to think about, that is, the manufacturers and producers, from a purely competitive point of view.

We say in one place in our report that if conditions warrant building for the greatest permanence with less regard for first cost, concrete construction may be useful. A few years ago this was true, but recent adjustments of prices have conspired to increase the cost of creosoted materials two-fold as compared with increased cost of concrete.

I hope the day is not far distant when we will have on San Francisco Bay a creosoting plant where it will be possible to obtain the materials with less likelihood of damaging the piling which now occurs, due to transportation, long periods of storage and continued handling. Some of the creosoted piles that we have received, although they are all tested by one of the largest testing concerns on the Coast, give a net penetration in places of ⅛ inch to ¼ inch. We know that the spikes on the raftsman's shoes will penetrate to the untreated wood with such a very slight penetration. So some means of overcoming the inequalities of the creosote oils throughout the sections of the piles should certainly be provided if we hope to obtain a uniform product and a uniform life. [*Applause.*]

PROF. CHARLES A. KOFOID: A report from a recent examination of concrete piling in the southern end of the State of a concrete pier which has stood for a number of years showed that there was considerable deterioration of the concrete above the water-line. The pier cost $35,000. The estimate for covering this exposed part of the concrete piles with creosoted wood and asphalt to preserve it is $28,000. [*Laughter.*]

MR. H. E. HORROCKS: I suppose the proof of this whole thing is as they say, the eating of the pudding. Now, I just want to give a little bit of history on the question of creosoted piles on this Coast. To my knowledge, extending over 8 years, our company has marketed at least 160,000 pieces of creosoted piling, ranging from 25 ft. to 125 ft. in length, and to the best of my recollection we have not had a complaint of failure or lack of sufficient penetration to the extent of a thousand pieces. That is the experience of only one company, one creosoting plant, on the Pacific Coast for only 8 years, and we have had in that same time at least 3 other plants producing creosoted piles, and probably the business of the creosoting plants on the Pacific Coast in that time has been 80% of creosoted piles, so that it is safe to say that in 10 years to 15 years past there have been well toward 300,000 pieces of creosoted piling marketed and sold to men and firms who are investing their own money on the Pacific Coast alone.

I would call your attention to one phase of industrial value of creosoted piling, and that is the question of obsolescence. On the central water front of Seattle—a lot of you gentlemen have passed through Seattle and you may have noticed—the docks were built from 15 years to 20 years ago with slips wide enough for the then modern vessels. I want to tell you that if you put an 8,000-ton Shipping Board vessel in one of those slips you cannot squeeze a launch between that ship and the other dock, so that portion of the water-front of Seattle has served its purpose and helped ahead the city of Seattle for 15 years or 20 years, and was built on creosoted piling. If you want to improve and modernize it, the only thing to do is to rip it all out and build it all over again. That, I think is a vivid illustration of the question of obsolescence as applied to the so-called permanent type of construction for docks.

The gentleman preceding me seems to infer that by some mysterious process the war prices on steel, concrete and kindred piling materials are beginning to decline, and by some equally mysterious process that the similar costs of creosote and what goes into creosoted piling would not decline. There is no force in the argument at all. There is nothing behind it. We are on the toboggan from pre-war prices, and what will certainly affect one will affect the other. When I cannot tell you, but the process of nature that is now having its way with regard to these matters will certainly affect creosoted piles as it will other materials.

I do not believe this report is what it ought to be. I do not believe that this report is emphatic enough in extolling the virtues of creosoted piling for water-front development purposes, particularly on the Pacific Coast. There is not any question in the world that it is justified in every way that you look at it. You cannot find a record of any piling material that has been used that will equal creosoted piling for marine work on the Pacific Coast and the East Coast. The entire water-front of the Pacific Coast, of Canada, and the United States, has been developed and brought to its present state on creosoted-pile foundations, and we have proof in the Southern Pacific work recently torn out here in West Oakland. We have the life of them here. The only reason we do not know about all this development is because it has not all been in use long enough. [*Applause.*]

THE PRESIDENT: I would like to call on Mr. Newman.

MR. NEWMAN: As regards the permanence of concrete structures in salt-water, I wish to call attention to a series of 5 articles which appeared in the "Engineering News-Record" for September and October, 1917, by Messrs. Ferguson and Wig, one of them the engineer of the Portland Cement Association, the other connected with the United States Bureau of Standards, in which these gentlemen reported the results of their examinations of practically all important American ports, and gave their conclusions as to the deterioration of the concrete structures found in those ports. The oldest structure, I believe, was 10 years of age, the latest had been built 1 year. They stated that of all the structures examined there were hardly any that did not show the marks of serious deterioration, and ascribed that deterioration principally to errors in design and poor workmanship. Now, they were not creosoting men, but concrete men, both of them.

As regards the price of creosoted piling, I have no doubt that within a few years after normal conditions have returned and we are able to get creosote where we formerly obtained it, the price will come down as other materials have come down, and, in this connection, I have here an abstract from an article by Mr. Charles W. Staniford, formerly Chief Engineer of the New York Department of Docks and Ferries, published in the Transactions of the American Society of Civil Engineers for 1914, in which, speaking of the use of timber in pier construction, he says:

> "With timber structures, the transformation or reconstruction is a simple, rapid and economical undertaking; it is difficult and costly with structures of stone, concrete, steel, etc. The use of concrete piles, rein-

> forced concrete sub-structures or similar forms of construction, therefore, would not only have resulted in high first cost of construction, but the difficulty and expense incidental to the periodical removal, reconstruction, or expansion of dock structures of this type, as necessitated from time to time by the growth of shipping, would have rendered harbor construction work, as a revenue-producing investment, practically impossible, and, consequently, would have greatly retarded the development of the harbor."

I believe that conditions in San Francisco are much the same as Mr. Staniford stated them to be in New York.

In the report of the Committee there is a reference to obsolescence of water-front structures in San Francisco Harbor. In 1909 the Harbor Commission came to the conclusion that our piers would not adequately handle business, and decided to build permanent piers of sufficient size to take care of the increased traffic. The old piers were 100 ft. wide by 650 ft. to 700 ft. long, with slip spaces of 150 ft. to 200 ft.; the new ones were made 130 ft. to 140 ft. in width and 700 ft. in length with 200-ft. to 220-ft. slip spaces.

In 1912, 3 years later, I took charge of the work, and, after consultation with numerous shipping men of the city, it was decided that the piers built in 1909 were too small and that the new ones to be built should be larger. The width was increased to 200 ft., the length to 800 ft., with slip spaces of 250 feet. In 1918, Mr. White, the present chief engineer, projected a series of improvements, which included piers 325 ft. wide by 1,000 ft. long, with 300-ft. slip spaces. There is no method apparent by which the idea of increased size required can be adapted to permanent structures, if they are permanent, and by which the harbor can be maintained at 100% efficiency.

It is true that some of the smaller structures can be used for coastwise business, as has been suggested, but the present coastwise business in San Francisco is only about 25% of the total; another 25% is carried on ferries and 50% is over-seas traffic, which, of course, comes in large vessels and needs large piers.

If we build now of permanent materials, and in 20 years or 25 years find that these materials are in piers that are too small to handle the traffic, we shall have to get along with them as best we can, because they will be too expensive to be torn out. In the meantime those who have built with temporary materials can afford to tear them out and replace them with modern structures, and we will be handicapped to that extent. Even at present with a large vessel of 12,000 tons or 15,000 tons berthed at a pier, there is constant interference between incoming and outgoing cargoes, and the 200 ft. by 800 ft. piers built since 1912 are too small.

There is a question I wish to ask Dr. Kofoid in regard to conditions in New York Harbor. As I understand, the teredo is not present there, but the harbor has considerable salt-water and it is also very much contaminated with sewage. Do you think that the absence of the teredo is due to the presence of sewage? Do you think that possible?

PROF. CHARLES A. KOFOID: Teredos live here in San Francisco Bay in sewage-contaminated waters. It is possible the question of food supply is very different in the 2 places, but I do not know. I have seen no report of the teredo in New York Harbor. There are few reports of it that far north.

MR. NEWMAN: There is another question in regard to the permanence of reinforced concrete structures. As I see it, based on experience with reinforced concrete cylinders and precast types, almost any form of concrete construction that requires the depositing of material in water is liable to speedy and serious deterioration, and is not to be counted on for permanence. The only 2 forms, in my opinion, are reinforced concrete piles and the precast cylinder enclosing the pile with the intervening space filled with grout or some other material. Our experience with these 2 forms, however, has not been sufficient to enable us to make an estimate as to duration of life.

The reinforced-concrete cylinder, I think, should be condemned on account of its excessive cost and the numerous opportunities for faulty construction.

As regards the use of creosoted piling, the producers of this material would find it to their interest to adopt precautions to insure proper handling, which has not been the case in the past.

The possibilities of faulty workmanship in concrete are as numerous in cases where the material is cast in place as they are with creosoted piling. In one of the concrete-pile piers that we built on the water-front, the first one of its type, in which some of the piles were 106 ft. long, I believe that fully 90% of the piles were driven without any injury to the head. They were seasoned for 45 days; and, by the way, the pier cost twice as much per square foot as a creosoted-pile pier, and the question is, will it last long enough to justify that extra cost. This, to my mind, is the essence of the entire matter.

MR. DEWINTON: As an interested onlooker, not belonging to the manufacturers of creosoted piling, this argument presents to me this feature: If I understood Mr. Brown's figures correctly there were 9 concrete piles in a cluster carrying the same load that he does with creosoted pile. If the concrete pile per foot only cost about 25 cents more, and the carrying capacity is about the same with concrete as with creosoted piles, as it stands today these arguments presented about avoiding durable construction therefore do not appeal to me. If the cost is going to be the same, why not build a durable pier and run the chance of its ever becoming obsolete in 25 years? The extra cost of the concrete pier seems to me is not so much, and I can see a very strong argument in favor of the concrete pile. It may last a great number of years and our sizes of docks may not become obsolete. [*Applause.*]

MR. H. E. HORROCKS: I just want to advance another argument as a creosoter and, if possible, bring more forcibly to the attention of every one here what Mr. Newman has said about the care and handling of creosoted pile.

If it is a question of relative economy, that is a simple matter, a comparatively simple matter as far as the figures are concerned, for engineers that handle work to know the actual comparative cost with concrete, but there is not any question in the world that if you take a creosoted stick, pile, timber, whatever it may be, handle it roughly and show the same lack of respect for it that is generally displayed for wood or timber piling just because it is wood, you are liable to destroy your entire investment the very first time you puncture it. I presume, not being familiar with the materials, that there are ways of handling concrete, concrete structures and concrete members in structures that will injure them, but I do know that the careless handling of creosoted material is a crime, and I want to repeat it is liable to nullify the investment return. We use extra care at the plants. We know what it means, and that it is the simplest thing in the world for a careless workman, if he is not properly directed, to spoil a creosoted pile or timber the first time he handles it.

MR. E. O. FAULKNER: We are talking about creosote for creosoted piles. What are we getting? What is now standard for the old kind of creosote? Are they giving us coal-tar creosote mixed with wood-tar, or gas-tar, or some other mixed tar or composition, and calling it creosote? The life of creosoted piling depends so much upon the quality of the creosote that I think we should know exactly what kind we are talking about.

PROF. CHARLES A. KOFOID: Mr. Chairman, there is one point the last speaker raised that is a matter of considerable biological importance and also engineering importance, that is, to determine the repellent substance in the creosote that prevents the larvæ of the teredo from settling on the pile, and it will take the engineer and biologist combined to determine upon those points and bring them to a satisfactory conclusion. It is, so far as we can get at it from the biological side, a matter of the repellent activity of the creosote that the larvæ will not bore into that wood for some reason, probably because it tastes the creosote.

DR. HERMANN VON SCHRENK: I am very glad Dr. Kofoid brought out that particular phase of this subject. I want to take this occasion to express my appreciation, which I know all of us feel for this most fundamental work that this Committee has started, and express the hope that this is a start and they will keep on with this type of investigation in spite of what has been said on the part of some of our enthusiastic friends about creosoted piling. We cannot close our eyes to the fact that we have had some fine creosoted piling, treated according to the best knowledge of the times, that has not stood the test of the action or destruction of the teredo.

For instance, last week I was down South and examined some piling in our southern gulf coast waters. The material had been treated so far as we knew with the best specification coal-tar creosote with an excellent penetration of the pile. The oil had penetrated to such an extent that you could squeeze it out with a vise. nevertheless, the teredo was in it.

I was particularly impressed with the presentation tonight, because of the fact that this is more than a problem of San Francisco Bay. These marine borers occur all along our salt-water coasts, and while we have some records in the Gulf of Mexico and Atlantic Coast and some on the Pacific Coast, they are all extremely full of gaps.

The particularly impressive part of this report is the wisdom which the Committee has so strikingly shown in regarding this problem as not one simply for the creosoter, but fundamentally a biological and a physical problem, which has to be studied very seriously before we can hope to write the specification which the last speaker called attention to which will show us how not only to treat the piling, but how to handle it in order to get the maximum service therefrom, and I hope this Association will very strongly endorse the recommendation of your Committee that they go on with this work, not only with the viewpoint of San Francisco Harbor, but as to the possible effects that this kind of work may have upon the salt-water engineering structures in other parts of this country, and finally prepare a specification as suggested by Mr. Faulkner.

MR. FRANK G. WHITE: I just want to mention one or two points that have been made in previous discussions. There was some criticism directed at the Committee because it was not sufficiently laudatory of creosoted piles, and also mention was made of experience in other places.

Now, this was a report of the San Francisco Bay Marine Piling Committee, and it was a survey of conditions on San Francisco Bay, and that particular question was discussed a number of times as to whether this Committee should go outside this particular district in furnishing any information or drawing any conclusions. The decision was that this investigation would be limited strictly to San Francisco Bay, and insofar as possible it should deal entirely with facts, and that is what the Committee has tried to do in drawing its conclusions and presenting the facts regarding creosoted piling. The Committee has attempted to give only facts and to draw no conclusions which could not be backed up by those facts. That is true not only of the creosoted piling but of the other types of construction which have been mentioned, and while mention has been made of the destruction of reinforced concrete structures in Southern California after a life of 10 years and a structure along the Atlantic Coast, again I say the Committee was dealing with facts as it finds them in San Francisco Bay, and those facts are that pre-cast concrete construction in San Francisco Bay having a life of 10 years at the present time shows absolutely no signs of deterioration. We do not know how long it is going to last, and we make no statement as to how long it would last. We simply said it had undoubtedly a long life yet.

As far as costs are concerned and the probable decrease in the cost of creosoted piling, there again we are dealing with facts, and the facts are that the creosoted piles at this time are high and what they may be in the future we do not know. We hope they will be lower, but we are dealing with facts as to the price of creosoted piling at this time as compared with concrete construction. [*Applause.*]

MR. A. E. LARKIN: Referring to the quality of oil that has remained in the piling which has withstood the ravages of decay and the marine borers all these years, your attention is called to parts of the PROCEEDINGS of 1920 where it is plainly shown that the oil taken from piling that has remained in serviceable condition for 29 years is the more stable portions of the oil and practically only the higher boiling parts of the oil. The analysis referred to shows that the oil that has preserved this piling during that period is the oil found in the piling, the balance of the oil, namely, the more volatile parts of it, having left the piling before it was examined, if, indeed, any oil except the heavier portions was used in the first place. The records are not clear as to just what kind of oil was used in the treatment of this particular piling.

It is clear, however, that the largest part of the oil remaining in the piling was that portion boiling above 235° and having a specific gravity of 1.11 and 1.12.

This demonstrates to us that there is no need of introducing as a preservative any oil but the pure high-boiling creosote oil that is stable and that will not volatilize, but that will remain in the piling indefinitely, just like the oil that has been found in the piling after 29 years of service.

MR. C. M. TAYLOR: It seems well for someone to make a motion to thank this Committee for bringing in such excellent facts that they have gotten together of the conditions in San Francisco Bay. I have been interested in marine piling for a good many years, and no one part of the country has undertaken and developed such remarkable data as this Committee has done. As Mr. White has so plainly stated, they have given only the facts of the case as they exist, and I must congratulate the Committee for being so true to conditions as it found them in the report. I cannot feel that anybody can say one way or another but that it has followed the facts as it found them, and I would like to make a motion at this time thanking the Committee for the work it has done and trust that it may see its way to proceed with this work, which needs the cooperation of such a loyal and enthusiastic body as it has had this last year.

DR. HERMANN VON SCHRENK: I second the motion.

THE PRESIDENT: Gentlemen, you have heard the motion and the second. All in favor respond by saying "aye"; contrary, same sign; it is so ordered.

MR. A. A. BROWN: I hope that none of our good friends have felt that I have an axe out for creosoted piling, for I am not selling concrete; I am not selling cement; I am not selling creosote, but simply using the materials in construction. Now, there are defects in the treatment of creosoted piling I think we ought to note, and if possible we ought to correct them.

We should make every material that we are using the very best material possible, whether that be creosoted or concrete. The work that has been done I think would be very largely lost if not continued. We are, for instance, at our plant, tearing out old piles and will continue to tear them out for the next 2 or 3 months, and then we will leave in a sufficient number of old piles that will enable us to break off 1 or 2 every week through the entire period of fresh-water to determine, if possible, the time at which the teredoes are exterminated, if they are ever exterminated.

We have an interesting condition at Crockett today. Our barges go out into the middle of the stream and get fresh-water. At the dock we have 50 parts per 100,000 of salt, in-shore 100 ft. we have 100 parts and still farther in we have 250 parts, and there are places, no doubt, where we have probably 500 parts of salt per 100,000, notwithstanding that a few feet off the stringer you can get 8 parts per 100,000. It is evident then that some of the teredoes will probably last throughout this season, at least we think they will. We are going to watch it and see whether they do. Then we have new samples to see when the breeding season begins. It would be a very great mistake, I believe, if we stopped the investigation at this point when we are really beginning. It is going to take many years to accumulate service-data that will be of genuine help in marine construction and that is what I believe we are all working toward now.

I would like to move that this investigation be continued throughout the coming year, and I hope it will be continued from year to year. The local committee, I presume, will have to arrange very largely to finance the continuation of the work.

THE PRESIDENT: Gentlemen, Mr. Brown has made a motion that the work be continued. Is there a second to that motion?

DR. HERMANN VON SCHRENK: I second the motion.

MEMBER: I would like to ask if Mr. Brown intended that the Committee should continue its work only in San Francisco Harbor. We have with us practically all the representatives of the East on the lumber question, and I would like to incorporate with that an invitation to make some investigation and send it back to us.

MR. A. A. BROWN: Our work here should be limited to San Francisco Bay, for the physical reason that we cannot get about to widely separated points. If it is the desire of this organization that the investigation be extended to other sections I believe a committee appointed from the Southern States, and one from the Atlantic Coast could initiate and carry it through, but our work here I think is of sufficient magnitude to command all of our attention, and we should not spread ourselves out so as to be ineffective and inefficient.

THE PRESIDENT: I think Mr. Brown has answered the question very nicely.

MR. GEO. M. HUNT: It seems to me that in order to get this work started and under way as quickly as possible, to get some idea of exactly what the Committee can do and what it cannot do in the way of raising money, and to decide in what ways the money they can raise can best be spent, a sort of steering committee should be appointed, a small committee, to study the matter for a short time and perhaps plan what should be undertaken for the year and make recommendations to the Executive Committee as to the nature and size and personnel of the larger Committee which it might be desirable to appoint later. I believe it would be better to start out with a small committee this year and in a few weeks enlarge it, than to start out with the whole committee and try to get them together, so I should like to move as an amendment to Mr. Brown's motion that a committee of 5 be appointed by the Chairman to outline this work and make the plans and recommendations to the Executive Committee.

(Motion seconded.)

THE PRESIDENT: All those in favor will say "aye"; contrary, same sign; it is so ordered.

MR. W. H. KIRKBRIDE: Mr. Chairman, I move that a vote of thanks be extended to the firms and individuals that contributed financially to make this report a success.

MR. A. A. BROWN: Second the motion.

THE PRESIDENT: It has been moved and seconded that a vote of thanks be extended to the firms and individuals who contributed to this work. All those in favor respond by saying "aye"; contrary, same sign; it is so ordered.

If there is no further business we will stand adjourned until 10 o'clock tomorrow morning.

WEDNESDAY MORNING SESSION

January 26, 1921

THE PRESIDENT: The meeting will please come to order. We have a communication from the Chairman of our Committee on Treating Plant Insurance. This Committee was appointed late in the year, and has not had an opportunity to organize and make a formal report. The Committee wishes to be continued in order that it may make a proper report for next year. The matter will be referred to the Executive Committee.

In the middle of last year we appointed a Committee on Industrial Ties, a rather unusual committee. A preliminary report has been handed in, and we will ask the Secretary to read this report.

REPORT OF COMMITTEE ON INDUSTRIAL-TIE SERVICE

To the Members of the American Wood-Preservers' Association:

As the Industrial-Tie Service Committee was not born until the fall of 1920 we have not been able to acquire much data on our subject.

The object of this Committee is to study and record the service rendered by treated ties in industrial tracks, under widely varying conditions, and so secure reliable information on which to base suggestions and recommendations as to the kind of ties and treatment best suited to meet various industrial track requirements.

By industrial tracks we mean switch-tracks, siding-tracks, yard-tracks, etc., in and serving industrial plants.

Most industrial-tie users have had little or no experience with treated ties, and in consequence do not, in a full measure, realize the economies that will result from their intelligent use.

It is right at this point that this Committee can be of the greatest value to our Association, by stimulating interest in treated ties, timbers, etc., for industrial plant use, disseminating information on the subject, and offering suggestions to solve the individual problems as presented.

The entire membership of this Association can cooperate with us along this line by referring inquiries of this nature to us, with the assurance that all such inquiries for information will receive careful consideration and prompt response.

We will, in turn, have to ask for help from our best informed members when puzzling questions arise which we find ourselves unable to answer authoritatively.

So far as its relation to the industrial-tie trade is concerned, this Committee now finds itself in a position about analogous to that of the wood-preserving industry at its inception, except that we have the knowledge and experience of this Association to guide and assist us.

For the reasons set forth it is only possible in this report to outline the object of this Committee, and under the conditions we respectfully recommend that the Committee be continued for another year.

H. B. KEHOE, *Chairman*,
A. W. ARMSTRONG,
W. H. CLIFTON.

THE PRESIDENT: If there is no objection we will accept the report of the Committee as information, and refer it to the Executive Committee.

We would like to make a change from the original program and have the paper on "History and Growth of the Treated Wooden Silo," by Keller J. Bell. We will ask Mr. Crawford to present this paper.

HISTORY AND GROWTH OF THE TREATED WOODEN SILO.

By Keller J. Bell.*

Some 3 months ago the Chairman of your Program Committee asked me to prepare a paper on the "History and Growth of the Treated Wooden Silo," and after some 10 years' experience in the manufacture, sale and construction of this form of silo, I venture to give you some of the results which we have obtained.

History of the Silo.

It is hard to state with certainty just when the first silos were constructed in the United States, possibly as soon as the early '80s. My father located among the Pennsylvania Dutch in Pennsylvania, started feeding silage in 1892, and although I did not go into the manufacture of silos myself until 1908, the nature of my former business was such that I have been in touch with the different forms of silo construction for nearly 30 years.

The silos that were constructed 25 or 30 years ago were all made of wood and were entirely what we termed "homemade structures," the most common construction being the placing of 2x4's or 2x6's on end in a circle and lining them around the inside with 2, 3 or 4 thicknesses of thin boards bent in a circle and nailed to the inside of the uprights. It was the usual custom to place at least 1 thickness of paper between each layer of boards.

This construction, when properly erected, made an air-tight silo, but it was impossible to get a smooth surface on the inside. Consequently, there was quite a bit of friction on the inside of the wall which prevented a proper settling of the silage. The above construction was practically abandoned some 10 or 15 years later, on account of the fact that moisture would get in between the different layers of boards and rot them in a comparatively short time.

The next construction was what is commonly known as the "plain-stave" silo, which kept the silage perfectly when properly constructed, and would last a reasonable length of time, provided clear heart lumber was used, but where any considerable part of the staves were sap the sap part decayed in a comparatively short time, which made the silo useless.

The main objection, however, to the "plain-stave" silo was the fact that it was almost impossible to keep it standing erect as well as to keep the walls air-tight, the chief reason for this trouble being that the staves were constantly swelling and shrinking. When the silo was empty the staves would dry out. If the user failed to keep constantly tightening his hoops, the silo would get loose and collapse. If he used care and kept the hoops tight and filled the silo without loosening the hoops the steam and moisture that came from the curing of the silage after the silo was filled would swell the staves to such an extent that they would often buckle or burst the hoops.

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*President, Western Silo Company.

In the Eastern and Northern States, where the silos are comparatively small, the "plain-stave" silo gave reasonably good satisfaction. There are thousands of them in use today, and a great many of them are being sold each year, but in the open country (by which I mean, the corn-belt—Indiana, Illinois, Iowa, the West and Southwest) where the silos were not usually protected by large barns and where the winds are much stronger, so many of them collapsed that both the users and prospective purchasers of silos sought a different construction and, as a consequence, beginning about 1907 or 1908, there were a great many cement monolithic and hollow-tile silos erected.

Essentials of a Good Silo.

I might state right here that the history of silos had advanced to such a degree that users of silage were beginning to understand some of the essential features of a good silo. These were: the silo must be permanent, that is, the material of which it is constructed must not rot, crack or deteriorate; it must not shrink or swell, due to the adverse conditions under which it is subjected when full and empty; it should be waterproof and air-tight, and it must be constructed of material that will retain the heat, that is, nonconducting.

A temperature of 100° to 120° is required to properly cure silage. At silo-filling time the average night and day atmospheric temperature is about 60° and it requires a temperature, on the inside of the silo, of about 120° to properly cure silage. It will, therefore, be seen that the difference between atmospheric temperature and that required to properly cure silage is about 60°.

Kinds of Silos in Use and Their Failure.

The untreated wooden silo has been pretty well described in the history and growth of the silo, as it was this form of construction that was first used, and in this make the real value of silage became known. We will now give a brief description of some of the other forms.

The masonry construction at first appealed very forcibly to the users, but they soon discovered, especially those who had used the wooden construction, that it was impossible to cure the silage in masonry without suffering a very considerable loss around the walls of the silo.

After the masonry silos had been up for several years it was discovered that they were not permanent structures in a great many instances, for the reason that the acid in the silage caused the cement or mortar to deteriorate to such an extent that this type became coarse and very rough on the inside, and many of the tile silos had be re-pointed at a considerable cost, notwithstanding the fact that it was almost impossible to re-point them and make them as tight as they ought to be in order to exclude the air.

In contrasting the masonry silo with the old wooden silo it is true that a wooden silo is more nearly air-tight than almost any known type, and this is often given as a reason why its silage is better than that cured in the masonry type.

But in my opinion, the principal cause for spoiled silage around the walls of masonry silos is largely a matter of temperature. Any type of masonry wall is only not a nonconductor of heat and cold, but is in reality a very good conductor, and as a consequence the outside and inside temperatures equalize around the inside of the wall of the silo, and the silage does not properly cure around the wall. In many instances this results in rotten silage, but in all cases there is a layer of dry, doughy and valueless silage around the inside of the wall.

Many farms have used masonry silos for years and still insist that they do not have any spoiled silage, but the greater majority of them, especially those who have had experience with wooden silos, have discovered that they really lose from 5% to 15% of the feed in a masonry silo over and above their maximum loss with a wooden silo. I watched this development very carefully, and decided about 12 or 13 years ago that if a permanent wooden silo could be produced that wooden construction would eventually be the commonly used type of silo.

By the masonry type above referred to we mean tile, concrete block, double or triple-walled brick, cement stave, stone or any form by which the pieces are cemented together by means of mortar. What has been said of the masonry silo can be said of the poured-concrete type, or of steel, or any form of metal. In fairness to the metal silo it can be said that it is more nearly air-tight, but it is also a splendid conductor of heat, and, therefore lacks the principal essential of a good silo.

Untreated or Superficially Treated Wooden Silos.

The untreated wooden silo does not fulfill all of the essentials of a good silo as stated above. Most of these failures have been brought out in giving the history of the silo, and what has been said with reference to the failures of the untreated wooden silo can be applied almost, if not entirely, to the superficially treated silo. I do not mean to state a superficial treatment with a good preservative has no value, but it has not the value, or nothing like the value, of a thoroughly impregnated silo, and one of the points I wish to discuss most in presenting this phase of the subject to the public is that many a superficially treated silo with a preservative of little or no value has been sold as a treated silo, based upon the reputation gained by a well treated silo by the pressure process.

Therefore, in discussing the merits and demerits of the superficially treated silo I wish to utter a word of warning, to beware of the superficially treated silo! Those superficially treated with a non-preservative have little or no value. The treatment is merely a ruse, while those superficially treated with a good preservative have a value no doubt equivalent to the cost of the treatment (if one is not made to pay for a full treatment), yet its value compared to its cost is low when contrasted with a silo well treated by the pressure process. It must not be forgotten that one of the principal essentials of a well-treated silo is that the treatment must prevent swelling of the staves, and this cannot be accomplished by a superficial treatment.

Treated Wooden Silo.

If I may be permitted again to refer to the history of silos I would like to state briefly the process we went through in attaining our present treated silo. During 1909 and 1910 3 or 4 of the largest paint companies in the country supplied me with different materials which I attempted to apply to the staves by the boiling process. In every instance this was an improvement over the plain stave, but I could not get sufficient penetration to prevent the staves from swelling when the silos were filled. I finally went to the United States Forest Service, and they suggested that I would probably get better results by using dead oil of coal tar or creosote by the pressure process.

Upon investigation I found that there were two well-known theories in the application of creosote by pressure, one known as the full-cell process, and the other as the empty-cell process. Upon looking into the full-cell process, I learned that it would not only be more costly than the empty-cell process, but that it was likely to leave the staves with the oil oozing out, making them sticky or gummy, and that this would be raised as an objection in the sale of the silos.

I further learned that there were two methods used in obtaining the empty-cell treatment, one known as the "empty-cell process with initial air pressure," and the other the "empty-cell process with final vacuum."

In 1911 I had several hundred thousands of staves treated with the "empty-cell process with initial air pressure." This treatment proved unsatisfactory for two main reasons. One was that the penetration was not sufficiently uniform in the same character of staves, and as a consequence portions of the staves would take moisture and swell. A further difficulty was that the staves would bleed after treatment, and farmers raised the objections that they were losing part of the oil for which they had paid, and that the treated staves were difficult to handle in erecting the silo. Consequently, I found that although my troubles had been partly eliminated, I had not yet effected a complete cure.

When I began the treatment of staves on a large scale in 1912, to my knowledge, I was the originator of the pressure-treated silos. By accident I learned that a silo had been treated by a Mr. S. S. Smith on a farm located 2 miles south of Bloomington, Indiana. I immediately visited this farmer, and inspected his silo. I learned that it had then been up about 3 years, and although he had never tightened a hoop, the silo was perfectly tight. There had been no seepage or bleeding of creosote from the staves since treatment. I secured 3 or 4 of these staves that were left over after the silo was erected, cut them in two, and discovered that the treatment was very much more uniform than was found to be the case with the staves I had been using

Upon further investigation I learned that these staves had been treated by the "empty-cell process with final vacuum," and in 1913 I made a contract with a creosoting firm who used this process. By slightly modifying this process to meet the conditions under which silo staves were subjected, we feel that we have now thoroughly eliminated our troubles, and that at last we have a silo that absolutely meets all the essentials necessary to a good silo. We have tested hundreds of staves treated by the process we are now using, and never in a single instance have had one of them to swell. We made these experiments largely by submerging the entire stave in water, leaving it in the water from 24 hours to 2 weeks. We would then take the stave out of the water and rub the surface water off and re-weigh it, and as a result found that it had not increased in weight more than from 1% to 3% and that there was positively no swelling.

During the past 8 years we have sold about 16,000 silos. Our business is growing rapidly, especially where we have the treated silo introduced, and I am of the firm belief that we have a silo that will absolutely predominate silo construction in the future.

We fully expect a length of life of from 35 years to 50 years from these silos. We have many silos that have been up 5, 6 or 7 years that have never had a wrench on the hoops. In other cases the hoops have only been gone over once, in the middle of the first season. We always recommend this, because there is bound to be a slight shrinkage if the staves are not perfectly dry when treated, or if they are treated during a wet season. There is also a certain amount of settling in the joints of the staves after the silo is erected.

THE PRESIDENT: Gentlemen, you have heard the paper. We are ready for discussion. If there is no discussion on this paper we will call on Mr. Horrocks and his Committee to present reports on the specifications for the treatment of creosoted Douglas fir paving blocks.

MR. CARL G. CRAWFORD: Mr. President, I have a little matter to bring before the Association that for various reasons I would like to present at this particular time. I think you will understand my reasons for bringing this up at this time as soon as it has been presented.

We have with us this morning one of our early members, Mr. David Allerton, and I would like to propose his name for Honorary Membership in this Association. I believe it requires at least 10 members to place a proposal for Honorary Membership before the Association. I am presenting Mr. Allerton's name on request of the following members: Dr. von Schrenk, Walter Buehler, E. J. Stocking, Carl G. Crawford, J. H. Waterman, O. C. Steinmayer, C. E. Gosline, E. E. Alexander, Andrew Gibson, R. F. Hosford, A. E. Larkin, R. L. Allardyce, S. D. Cooper, R. S. Belcher, F. D. Mattos and L. C. Drefahl. I would like to make a motion at this time to admit Mr. Allerton to Honorary Membership in this Association.

MR. F. J. ANGIER: I would like to second the motion.

THE PRESIDENT: It has been regularly moved and seconded that Mr. David Allerton be made an Honorary Member of our Association. Are you ready for the question? All in favor respond by rising. (All the members rose to their feet.) It is so ordered. [*Applause.*]

MR. DAVID ALLERTON: Gentlemen, I thank you. This has been most unexpected, and you will, therefore, not expect me to make an extemporaneous speech, except to say I sincerely thank you. [*Applause.*]

THE PRESIDENT: Will the Committee on Douglas Fir Paving Blocks please come forward?

REPORT OF COMMITTEE NO. 5-3—SPECIFICATION FOR TREATMENT OF CREOSOTED DOUGLAS-FIR PAVING BLOCKS.

To the Members of the American Wood-Preservers' Association:

Timber.

(1) KIND.—The wood from which the blocks are to be manufactured shall be Douglas fir. The blocks must be sound and must be well manufactured, square-butted, square-edged, free from unsound, loose or hollow knots, knot holes, worm holes, and other defects, such as shakes, checks, etc., that would be detrimental to the blocks. The upper half of the block shall be entirely free of knots. Blocks shall show at least 6 annual rings in each inch measured radially. Sapwood shall not be considered a defect.

Size of Blocks.

(2) The blocks shall be from 5 to 10 inches long, but should preferably average 2 times the depth; they should be 4 inches in depth for very heavy traffic streets, 3½ inches in depth for moderate traffic streets, and for light traffic streets they should be 3 inches in depth; but where 3-inch blocks are used no block shall be longer than 8 inches. They shall be from 3 inches to 4 inches in width, but in any one city block all of them shall be of uniform width. A variation of 1-16 inch shall be allowed in the depth and ⅛ inch in the width of the blocks from that specified. In all cases the width shall be greater or less than the depth by at least ¼ inch.

Preservatives.

(3) Coal-Tar Oil.—The oil shall be a coal-tar product, of which at least 65% shall be a distillate of coal-gas tar or coke-oven tar, and the remainder shall be refined or filtered coal-gas tar or coke oven tar.

It shall comply with the following requirements:

(1) It shall not contain more than 3% of water.

(2) It shall not contain more than 3% of matter insoluble in benzol.

(3) The specific gravity of the oil at 38° compared with water at 15.5° C. shall not be less than 1.07, nor more than 1.12.

(4) The distillate, based on water-free oil, shall be within the following limits:
Up to 210° C., not more than 5%.
Up to 235° C., not more than 25%.

(5) The specific gravity of the fraction between 235° C. and 315° C. shall be not less than 1.03 at 38° compared with water at 15.5° C.

The specific gravity of the fraction between 315° C. and 355° C. shall be not less than 1.10 at 38° compared with water at 15.5° C.

(6) The residue above 355° C., if it exceeds 35%, shall have a float-test of not more than 80 seconds at 70° C.

(7) The oil shall yield not more than 10% coke residue.

(8) The foregoing tests shall be made in accordance with the standard methods of the American Wood-Preservers' Association.

DISTILLATE OIL.—The oil shall be a distillate of coal-gas tar or coke-oven tar. It shall comply with the following requirements:

(1) It shall not contain more than 3% of water.

(2) It shall not contain more than 0.5% of matter insoluble in benzol.

(3) The specific gravity of the oil at 38° compared with water at 15.5° C. shall be not less than 1.06.

(4) The distillate, based on water-free oil, shall be within the following limits:

Up to 210° C., not more than 5%.
Up to 235° C., not more than 15%.

(5) The specfic gravity of the fraction between 235° C. and 315° C. shall be not less than 1.03 at 38° compared with water at 15.5° C.

The specific gravity of the fraction between 315° C. and 355° C. shall be not less than 1.10 at 38° compared with water 15.5° C.

(6) The residue above 355° C., if it exceeds 10%, shall have a float-test of not more than 50 seconds at 70° C.

(7) The oil shall yield not more than 2% coke residue.

(8) The foregoing tests shall be made in accordance with the standard methods of the American Wood-Preservers' Association.

Treatment.

(4) The timber may be either air-seasoned or green. Green timber and seasoned timber shall not, however, be treated together in the same charge. The blocks shall be treated in an air-tight cylinder with the preservative agreed upon. They shall be treated by the boiling process, substantially, as follows:

The charge shall be boiled in creosote at not to exceed 190° F., under vacuum of at least 20 inches for 2 hours and not to exceed 6 hours depending upon the degree of dryness of the timber. Pressure shall then be applied not exceeding a maximum of 125 lbs. until the preservative has been absorbed in an amount about 3 lbs. per cubic foot in excess of the specified quantity.

The temperature of the surrounding creosote shall then be raised to and held at 225° F. for 1 hour. The creosote is then exhausted from the retort, the steam is shut off from the coils and a quick vacuum of 20 inches to 25 inches applied for a period of 30 minutes to 1 hour.

In any charge, the blocks shall contain at least 12 lbs. of water-free oil per cubic foot of wood at the completion of the treatment. The blocks after treatment shall show the preservative well diffused throughout the wood, and the sapwood shall be entirely and well treated. To determine this at least 25 blocks shall be selected from various parts of each charge, and if more than one of the blocks show untreated sapwood, the charge shall be again treated. After re-treating, the charge shall be again subjected to a similar inspection.

The surface of the blocks, after treatment, shall be free from heavy pitch or tar-like deposits, and all blocks that have been materially warped, checked or otherwise injured in the process shall be rejected.

Handling Blocks After Treatment.

(5) The blocks shall preferably be laid in the street as soon as possible after being treated. If they cannot be laid immediately, provision shall be made to prevent them from drying out by stacking in close piles and covering them, and, if possible, by sprinkling them thoroughly at intervals. In any case, where they are not laid as soon as they are received on the street they shall be well sprinkled about 2 days before being laid under the direction of the purchaser. It is important to have the wood sufficiently wet to be swelled to its maximum size before it is laid.

Inspection.

(6) All material herein specified and processes used in the manufacture of the blocks therefrom shall be subject to inspection, acceptance, or rejection at the plant of the manufacturer, which shall be equipped with all the necessary gauges, appliances, and facilities to enable the inspector to satisfy himself that the requirements of the specification are fulfilled.

The purchaser shall have the further right to inspect the blocks after delivery upon the street for the purpose of rejecting any blocks that do not meet these specifications, except that the plant inspection be final with respect to the kind of wood, rings per inch, oil and treatment.

H. E. HORROCKS, *Chairman.*
WALTER BUEHLER.
H. M. NEWTON.

MR. H. E. HORROCKS (Chairman): Mr. Chairman, the only essential thing in the modification of the specification for the treatment of pine blocks is that we provide for the differences in the timber, Douglas fir requiring a somewhat different handling in treatment. Consequently, the specification we have prepared is like the pine-block specification, except in those particulars, and there are just a few details. A reprint, or a copy of the specification for the treatment of pine, was adopted. In fact, we copied in toto the specification for preservatives, and I believe that applies also to the handling of blocks after treatment, that specification being in our opinion an excellent one. This is published, and I do not believe it is necessary, unless you desire, to read it at the present time. I might just add that this is probably of no interest to many members of this Association, only a few, just really those of us on the Pacific Coast at the present time. That is, you are not vitally concerned in it, and I believe that it is in proper condition for adoption by this Association.

THE PRESIDENT: Gentlemen, you have heard the report of the Committee. A motion will be in order to accept the report and refer it to the Executive Committee for acceptance by letter-ballot in the usual manner. Is such a motion made?

MR. C. M. TAYLOR: Mr. Chairman, I move this report be accepted and submitted by letter-ballot to the Association for adoption as proper for our MANUAL.

MR. O. C. STEINMAYER: I second the motion.

THE PRESIDENT: It has been regularly moved and seconded that this report of the Committee be accepted and referred to the Association by letter ballot for acceptance as standard practice and inclusion in our MANUAL. All in favor respond by saying "aye"; contrary, same sign; it is so ordered.

The next paper to be presented will be that by Mr. Hoxie, "Treated Lumber For Insulating Roofs of Moist Factories." Mr. Barth will please read this paper.

TREATED LUMBER FOR INSULATING ROOFS OF MOIST FACTORIES.

By F. J. Hoxie.

A new use for treated boards and planks is developing for the heat insulation of roofs of cotton-weaving mills and paper mills. The object is to stop the rot which is rapidly progressing in them by keeping the temperature above the dew point of the air in the room below. Two such roofs were installed 2 years ago, in New England, and are giving good results, not only in stopping rot, but in preventing sweating which has been troublesome in cold weather.

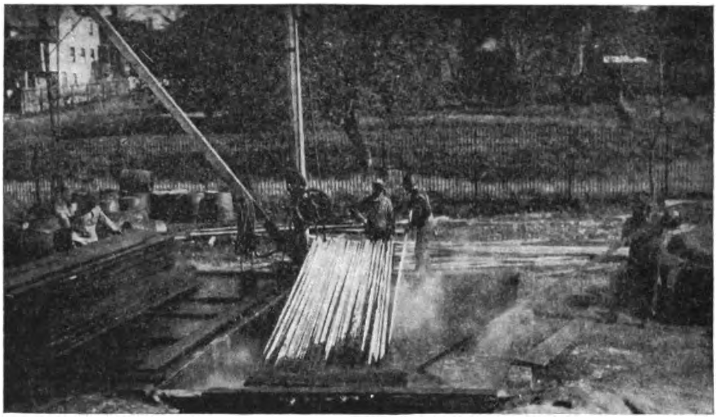


Fig. 1.—Treating ⅞ inch by 10 inches Boards in an Open-Tank, the Boards Being Placed on Edge to Facilitate Circulation of Liquid.

At present a Rhode Island weaving-mill roof is being covered with seven-eighths North Carolina pine treated boards. This will require 130,000 feet of lumber, which is being treated in an open tank in the mill yard. The concrete treating tank is shown in Fig. 1. An absorption averaging 6 lbs. per cubic foot was obtained, although some of the light boards are taking up 12 lbs.

Fig. 2 shows several sections of the treated boards. The section at the top is exceptional. This is of dense Southern pine and has absorbed but little oil, and shows slight penetration. The temperature of the oil exerts a greater influence on the penetration than the time of contact, very little penetration being obtained in 20 hours below the boiling point of water. At 220° F. an absorption of 6 lbs. per cubic foot is obtained in 20 hours.

Water in the wood seems to have little, if any, bad effect, if the temperature of the oil is above the boiling point of water, and the wood is kept in contact with the oil for 20 hours or more. In order to get some data at this point a piece of North Carolina sapwood was soaked in warm water over night, with the result that it was nearly water-logged. This piece was then placed in the hot oil with a batch of lumber and took up 12 lbs. per cubic foot over night.

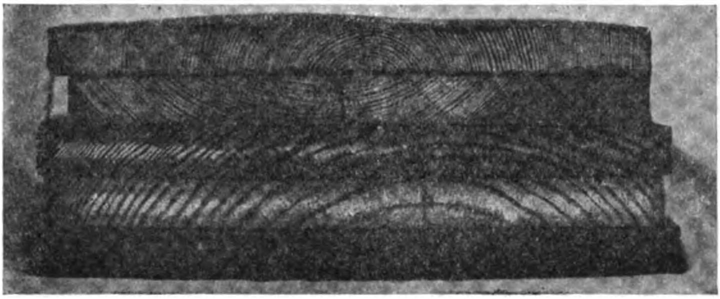


Fig. 2.—Sections of 5 Boards, ⅞ inch by 10 inches, Treated for 20 Hours at 220° F. in an Open Tank, Absorption Varying from 1 lb. to 12 lbs. per Cubic. Foot with an Average of 6 Pounds.

When the treated boards were put on the roof the slag of the old roof was scraped off one bay with chisels. This involved considerable expense, and somewhat damaged the tarred paper, as shown in Fig. 3. Therefore, on the remainder of the roof the slag was simply swept off with stiff brooms, as shown in Fig. 4.

The 2x⅞ sleepers were then nailed on, leaving a ⅞-inch air space under the insulating boards, the old slag roof remaining below the insulating covering to prevent the moisture from coming up into the air space from the highly humidified air in the room below. The present 2½-inch spruce-plank roof was installed 14 years ago, and has commenced to show unmistakable signs of rotting as shown in Fig. 5, although it still has sufficient strength to support itself and the new insulating covering.

The location of the rot and the extent to which it has progressed is indicated by black marks of the extractive material on the white paint of the beams and planks beneath, as shown in Fig. 6. The following plan of the roof on which the dark streaks are plotted as short black lines coming out from the lines representing the beams shows clearly the influence on the rotting which the heating pipes around the sides of the building and the ventilators on the roofs have exerted, as shown in Fig. 7. The extra heating pipes on the side walls kept the parts of the roof towards the outer walls slightly warmer than the remainder, and therefore, reduced the moisture below the limits of the requirements of the fungus, causing the destruction, while the heat escaping through the ventilators increased the moisture locally and accelerated the destruction.

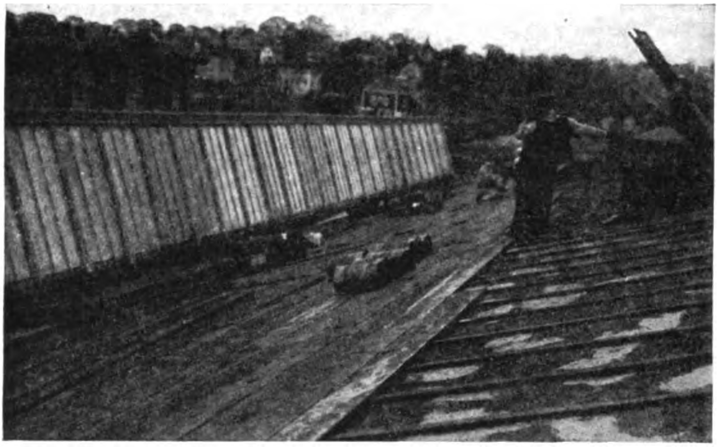


Fig. 3.—Applying the Insulating Covering to the Roof. On This Sawtooth the Gravel was Removed; Therefore, the Light-Colored Patches.

Fig. 4.—Slag Being Swept Off in Preparation for the Insulating Covering.

The indication of rotting given by these black lines of extractive matter can prove very useful in giving warning of a dangerous condition in the roof planks while there is still time to apply an insulating covering, and save the roof for some years at least.

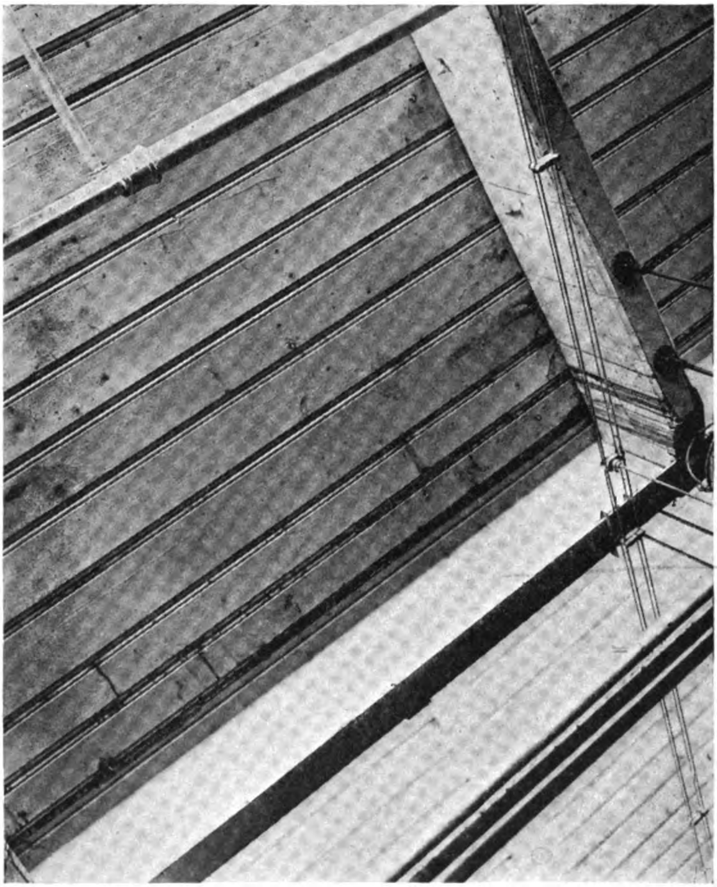


Fig. 5.—Base of a Sawtooth Inside the Mill, Showing Unmistakable Signs of Rot in Fungus Plants and Streaks of Extractive Material on the Beams.

Replacing the rotted planks of such a roof is by no means an infallible remedy, if the insulation or heating is not changed to keep the temperature below the dew point.

Fig. 6 shows part of 2 bays which are only 2 years old, and which are now the worst rotted planks in the entire roof, due doubtless to the lumber which was used containing considerable sapwood and having been kiln dried. Therefore, when subjected to the highly humidified air of the weaving mill the lumber swelled and made a tight surface and kept the liquid water in, which had passed into the wood as a vapor and condensed in the cooler interior.

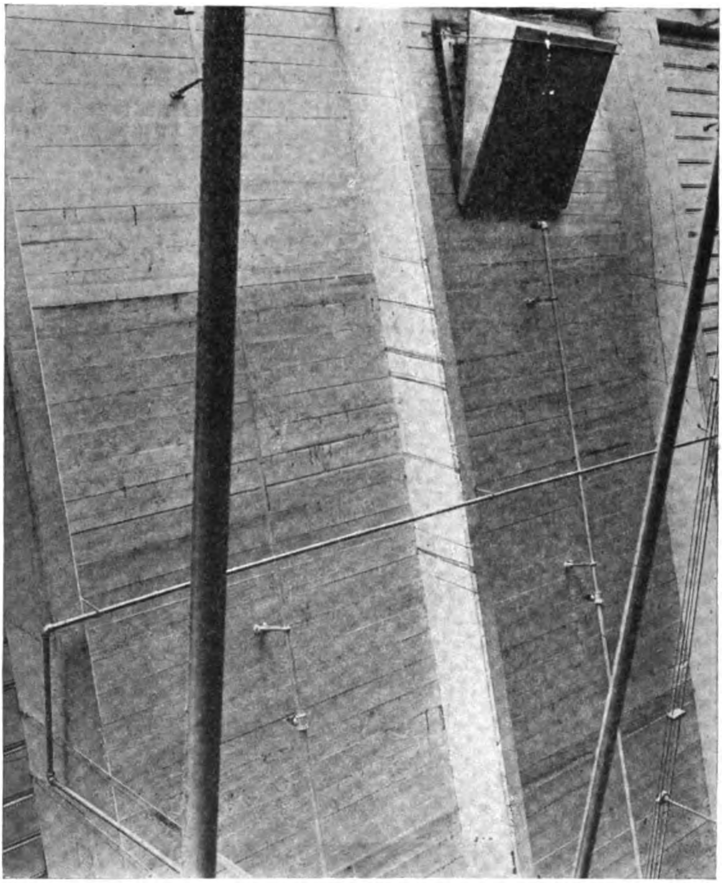


Fig. 6.—Shows Surface Indications of Rot.

The fungus plant most active in this destruction appears to be the *Lenzites Trabier*, some imperfect specimens of which are shown in Fig. 8.

A vacuum and pressure process of treatment would doubtless give a more thoroughly uniform treatment than the open-tank process, but it is frequently difficult to get vacuum and pressure-treated lumber promptly, particularly in small quantities.

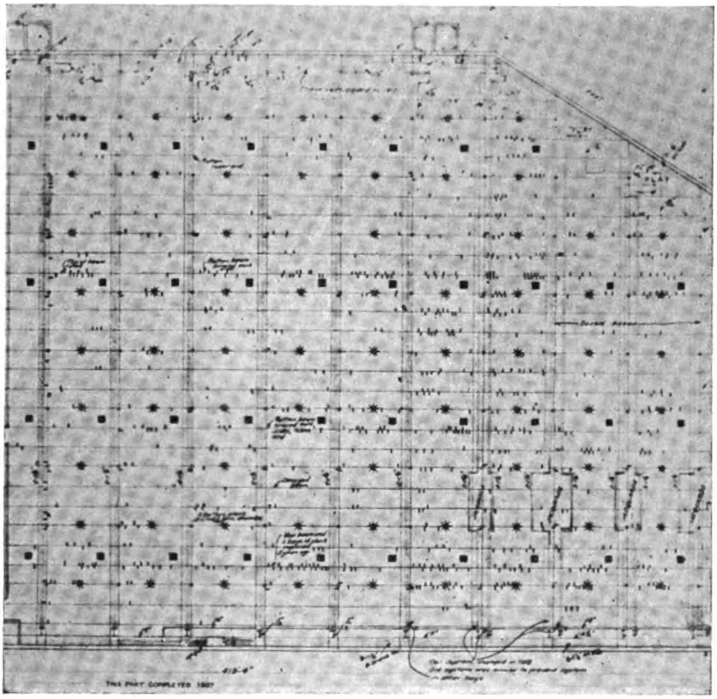


Fig. 7.—Plan of the Roof Showing Location and Extent of Rotting as Indicated by Dark Lines of Extractive Material on the Beams.

This form of insulation will considerably increase the life of a new roof, or a new roof can be made of heavy plank thoroughly creosoted and sheathed underneath having a thin air space, the sheathing serving as a painting surface and to prevent dripping.

The President: Gentlemen, you have heard the paper. Is there any discussion?

MR. C. M. TAYLOR: Mr. Hoxie, as you know, is in position to develop treated lumber in a lot of ways in construction, and this paper by him is an instance where he takes advantage of this proposition. It is only by such examples as this that we are going to be able to push creosoting and other timber treatment into all the different lines of timber construction. Mr. Hoxie is very enthusiastic about this and I trust we will have other examples of diversified uses of treated lumber.

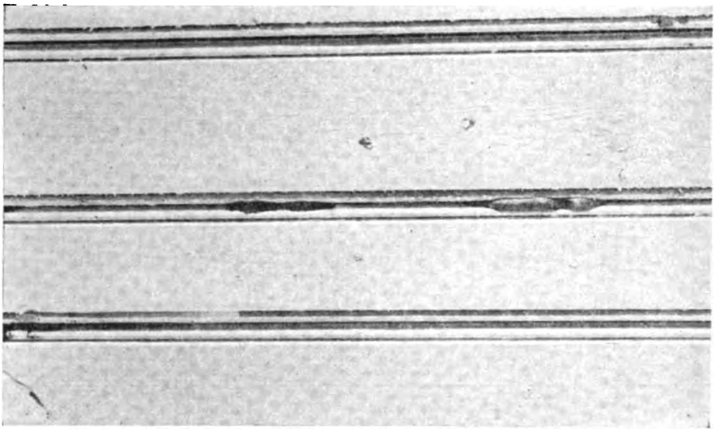


Fig. 8.—Lenzites Trabier Plant in a Crack Between 2 Planks.

MR. KURT C. BARTH: I would like to say a word about the work Mr. Hoxie is doing. He has 2 or 3 types of roof construction which he highly recommends for conditions of this kind. For reinforced concrete decks he recommends that the form lumber be creosoted, and after the deck has been poured the lumber is placed on top as insulation. Another type of roof that he recommends is an untreated ceiling, because of the necessity of painting with white the ceilings in weave sheds; then 3 layers of felt and pitch mopped solid; then the creosoted sheathing varying from ⅞ inch to 2 inches in thickness, depending upon the insulation required, then an ordinary 5-ply felt pitch and gravel-roof. Construction of that type will materially reduce, if not largely eliminate, the amount of condensation which accelerates decay in the wood-roof decks of paper-mills, textile-mills, round-houses, etc. Really, you see, there are numerous opportunities which we have not yet touched, but which are being developed, and incidentally, the use of the non-pressure treatments are educating people to appreciate what wood preservation means, and it is preparing them for the time when they may be able to obtain material treated by the pressure processes.

THE PRESIDENT: We will have presented to us the "History of Wood Pipe and Some Data on its Use," by Mr. E. J. Bartells.

MR. E. J. BARTELLS: Mr. Chairman and Gentlemen, I have a paper prepared on the subject which you all can read when you have time and want to do it. I have about 80 slides that I will run through, and make a few remarks on each slide, and it will be a little more entertaining than the prepared paper which you can refer to.

(Mr. Bartells then showed a number of slides with comments.) [*Applause.*]

HISTORY OF WOOD PIPE AND SOME DATA ON ITS USE.

By E. J. Bartells.

Ever since man has seen the necessity for conveying water by means of closed conduits, wood pipe has been in use. The first wood pipe was a straight log with a hole burned through the center, the log sections being joined into a continuous line by whittling one end to a taper, and inserting this in the enlarged end of the next length. This method was improved upon as time elapsed, largely through trimming the logs and more accurate boring, but the main features remained the same for centuries.

This type of pipe has been used for many years in Germany, Russia, England, Sweden and other countries.

Constantinople received its entire water supply through bored wood pipe for more than 2 centuries, and part of the city is still supplied in the same way.

Some of the earliest water supplies in London were derived from springs, but the greater part was raised by current pumps placed upon the bridges. From these pumps the water was distributed through wood pipe, of which London had several hundred miles, the sole means of water supply for over 200 years. Portions of these lines unearthed during modern excavations have been found sound and solid, and the original company, organized in 1619, still supplied a part of London.

About 1800 a great impetus was given to water supply in both Paris and London. It was at this period that much wood pipe was used, 1 company alone having nearly 400 miles. As many as 10 lines were laid, side by side, to form a single main.

It was not until 1865 that public water supplies were generally introduced and it has been only within the last 45 years that all civilized countries have undertaken a general and systematic water supply.

In the United States, as early as 1755, wooden pumps with boilers partly made of wood, and wood pipes were used.

In 1800, Philadelphia installed wood-pipe supplies by curious pumps, and to this day some of this old wood pipe when dug up is found to be in a remarkable state of preservation.

New York and many other cities obtained their first supply of water through wood pipe, and while the original lines in some cities have been discarded for larger and higher pressure pipe, many still retain their original wood pipe.

Portsmouth, N. H., used bored pine logs for mains from 1798 to 1896, when larger mains were required. The pipe was entirely sound when taken out.

Burlington's (N. J.) first water-works were built in 1804. The wood pipe was purchased from the city of Philadelphia, where it had been in use for many years

Boston used 1 system of wood pipe from 1652 to 1796, then replaced it with another, which lasted until 1848. In this city workmen a few years ago, employed by a contracting firm excavating to lay new mains on Elliot Street, unearthed 2,000 feet of wood pipes which R. A. Scally, the engineer in charge, believed to be 125 years old. The ancient pipes were in a remarkable state of preservation, considering the number of years they had been in the ground. It was evident to those who examined these pipes and their location that they were part of a system that extended from the region about the present west wing of the State House on Beacon Hill to a downtown point.

"The pipes were evidently used by the residents of this section of the city for household water supply," said Engineer Scally. After an examination he said that the wood of the old pipes was chestnut, and thought this quite remarkable, since chestnut is not one of the woods usually remarkable for longevity when exposed to adverse conditions, whereas there are some woods that may well be expected to last indefinitely when placed underground. The wood of these pipes was still sound and appeared serviceable for another century or so. "The pipes had what is known as a bell and spigot connection, which proved to be admirably adapted to the low-pressure system used in those ancient days. It is probable that only 10 lbs., 14 lbs., or possibly 15 lbs. pressure of water was in the pipes at any time, which is much less than the present modern high-pressure service."

Denver, Colo., for over 30 years has received its entire supply from mountain streams through 100 miles of wood-stave pipe. The first of these lines was built in 1886. The Denver pipe marked the real transition of wood pipe from bored logs to the modern steel-banded wood-stave pipe.

Some of the cities which receive all or part of their water through wood-stave pipe are: Astoria, Ogden, Butte, Salt Lake City, Reno, Dallas, San Diego, Lynchburg, Va.; Greensboro, N. C.; Temple, Tex.; Logan, Utah; Tacoma, St. Johns, New Brunswick, Nome, Alaska; Port Arthur, Tex.; Yuma, Ariz.; Provo, Utah; Vancouver, B. C.; Everett, Wash.; Pueblo, Colo.; North Platte, Neb.; Olympia, Wash.; Lovelock, Nev.; Nelson, Neb.; Honolulu, T. H.; Hurley, N. Mex.; Sisson, Cal.; Elko, Nev.; Kalispell, Mont.; Pocatello, Idaho; Cumberland, Md.; Waco, Tex.; Fort Bragg, Cal.; Coos Bay, Oregon; Clarkston, Wash.; Greenville, Tex.; Swanton, Vt.; Placerville, Cal.; Montpelier, Idaho; Twin Falls, Anaconda, Mont.; Wahiawa, Hawaii.

As an indication of the attitude of the authorities on hydraulics toward wood pipe, attention is directed to the following:

Mr. Hull, of Connecticut, who has had an experience of over 40 years with large wood-stave pipe, states in his letter to "Engineering News" (June 20, 1891), that he estimates the life of wood pipe, when entirely exposed and air circulating around it, at from 40 years to 50 years, and that he considers its life indefinite when buried underground.

On page 572 of "Public Water Supplies," by Turneaure and Russell, appears the following:

> "The necessity of water carriage in the west has developed a very different form of wood-stavee pipe. As early as 1874, Mr. J. T. Fanning built such a pipe which is still in use, but the chief development of this type of construction has taken place in the west since 1883, at which time stave pipe was first extensively used at Denver."

Mr. James D. Schuyler, M. Am. Soc. C. E., a distinguished hydraulic engineer, says in Vol. XXXI, Proceedings of the American Society of Civil Engineers.

> "At a moderate estimate, the saving effected by the Citizen's Water Company by the use of wood pipe for their main conduits has been no less than $1,100,000. The interest on this amount at 5% would renew the mains every 5 or 6 years, or duplicate them as often as that. With such a showing as this, the correctness of which cannot be challenged, there can be no doubt of the soundness and wisdom of the judgment which governed the selection of wood pipe as the material for the main conduits of this company. If this be admitted, why may not the experience be repeated anywhere, with equally favorable results?"

Advantages of Wood Pipe.

Wood pipe is recommended for a wide variety of purposes under greatly varying conditions. There are, however, certain restrictions placed on its use which are recognized by the wood pipe manufacturers. These manufacturers are making a strenuous effort to encourage the use of their product in those instances where its suitability has been demonstrated, and just as strenuous an effort to discourage its use for those purposes and under those conditions where its unsuitability has been proven. The reason why wood pipe manufacturers take this position is obvious—the greatest development of any industry depends primarily on the intelligent use of the product manufactured. With this idea in mind the advantages of wood pipe may be pointed out with exceptional clarity.

COST—The primary purpose of a pipe-line is to deliver water or other liquids from one point to another, this operation to be continued for a certain length of time, or more likely for an indefinitely long period. The low initial cost of wood pipe, the low maintenance cost, and the saving effected in interest charges by reason of low initial investment, make it the most economical pipe that can be installed regardless of the period of service required.

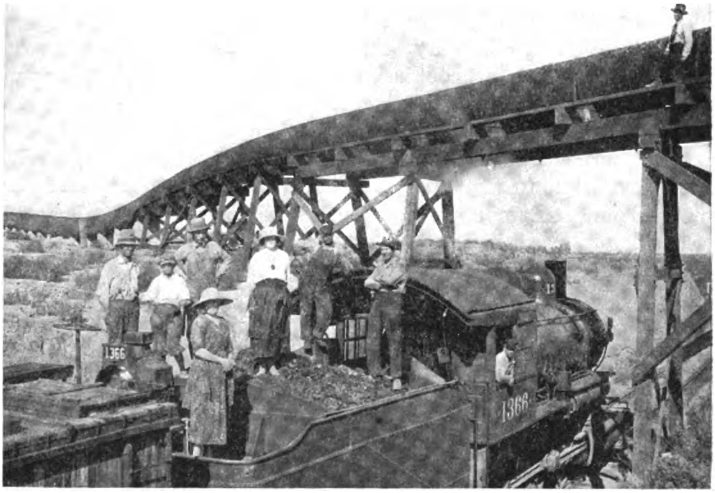
EFFICIENCY—The efficiency of any pipe-line is relative; that is, it may serve the purpose for which it is intended better or worse than a line constructed of other materials. Wood pipe, by reason of its smooth internal surface and its freedom from corrosion, tuberculation, or other action tending to reduce this original smoothness, is unquestionably the most efficient pipe yet produced.

CAPACITY—Efficiency and capacity are so closely connected that a reference to the one naturally suggests the other, and those qualities responsible for increasing efficiency are also responsible for a greater capacity.

That wood pipe has a greater capacity, size for size, than pipe of other materials, which are at times considered as substitutes, has been definitely established by the U. S. Department of Agriculture, and reported in Bulletin No. 376 by Fred C. Scobey.

In 1916 Mr. Scobey made a series of 64 tests on 16 separate pipe-lines, and from the results of these tests, together with the reports of many prominent investigators on this subject, has published a formula for the flow of water in wood pipe and also tables showing the capacity of different sizes of pipe.

As a result of Mr. Scobey's extensive investigations, his conclusion, as published on page 73 of Bulletin No. 376 is "that wood pipe will convey about 15% more water than a 10-year old cast-iron pipe or a new riveted pipe, and about 25% more than a cast-iron pipe 20 years old or a riveted pipe 10 years old."



ADAPTABILITY—While low cost and high efficiency and greater capacity are often determining factors, adaptability many times has led to the use of wood pipe regardless of other factors. A large proportion of the existing pipe-lines in use today traverses remote and inaccessible districts.

The transportation of materials of construction to the line of work, and the assembling of same into a complete pipe-line has proved a problem most easily solved by wood pipe. The smaller sizes of wood pipe are easily transported after assembling the sections, being light in weight and of convenient length. The larger sizes of wood pipe are transported in small units, namely, staves, bands and shoes, and assembled in place into a complete pipe-line. The length of staves and number of bands or shoes per bundle can be accommodated to the means of transportation without interfering in any way with the work of assembling or without reducing the efficiency of the completed pipe.

Pipe as large as 14 feet inside diameter is constructed of staves measuring approximately 4 inches by 6 inches in cross-section, and of any desired length up to 40 feet. Consequently, the construction of the largest pipe required offers no insurmountable difficulties to the wood pipe manufacturers' experts and their experienced crews.

Under adaptability may be mentioned also the fact that wood pipe is admirably suited for the construction of pipe-lines traversing country of uneven contour. Bends, sharp curves, or even spirals, if required, can be "built into the line" by the experienced crew. It is not possible for any other material to lend itself so readily to the installation of pipe-lines of this sort without excessive construction and assembling costs.

Types of Wood Pipe.

Wood pipe is manufactured in 3 different types: Wire-wound, continuous-stave, and bored. Each type is made especially to serve a specific demand.

Materials.

LUMBER—Wood pipe is manufactured from especially selected redwood, Douglas fir or creosoted Douglas fir. Other varieties of lumber have been used, but the superiority of these 2 western species has been well established.

Along a comparatively narrow strip of land, bordering on the Pacific Ocean, are found the enormous forests of Douglas fir and redwood where individual trees are found by the thousands of such gigantic size that they are economically handled only by reason of the development of special methods of logging and lumbering. These enormous trees yield that fine, clear grade of lumber so necessary for pipe staves, free from many defects common to smaller varieties.

WIRE, BANDS, SHOES—Owing to the insistent demand of the pipe manufacturers, a special double-galvanized pipe-winding wire has been developed for use in winding wire-wound pipe. For continuous-stave pipe, mild steel round bands with upset threads are used; these bands being especially made for this purpose.

Malleable-iron shoes made off the patterns of the pipe manufacturers, are used to connect the 2 ends of the bands. The wire, as well as the bands, are required to stand a test showing an ultimate strength of 60,000 lbs. per square inch of cross-section, and an elastic limit of one half that amount.

The shoes are required to be stronger than the bands with which they are used. This strength is attained both by the use of a high quality of malleable iron and by a proper design. Thus it will be seen that all materials entering into the manufacture of western wood pipe are especially selected and designed for the purpose.

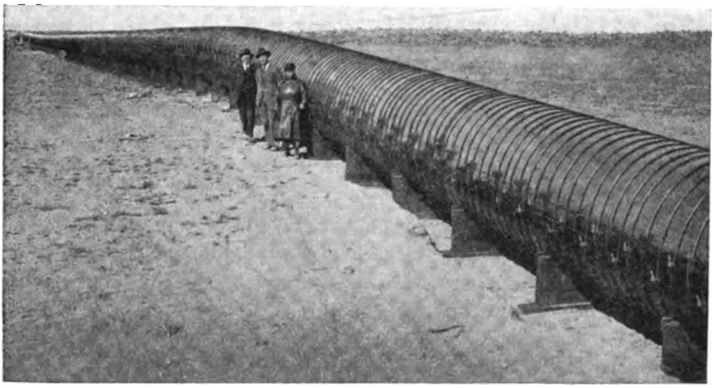
EXPERIENCE—Given the proper raw materials, the further requisites for the manufacture of a satisfactory product are facilities, namely, plant and equipment, and that specialized knowledge acquired by years of experience.

During the past 30 years or more, the wood pipe manufacturers of the Pacific Coast have evolved the present-day wood pipe from its earlier and somewhat crude beginning. Being supplied with unlimited raw materials, ample facilities for manufacture and construction, and equipped through years of experience with a full knowledge, the western wood pipe manufacturers are in a position to offer the public an additional value impossible to attain elsewhere—a thing, the importance of which Mr. George L. Watson, Consulting and Supervising Engineer, stoutly emphasized in a paper published in Vol. IV, No. 7, Journal of the American Society of Engineering Contractors. He said:

> "If we merely look at photographs of the completed work, the building of a wood pipe-line appears to be a very simple form of construction; perhaps to some engineers and construction men it is.
>
> "The writer is very chary about giving advice gratis, for what we get for nothing is not valued at much; but still a word of advice may not be amiss. The contractor who is fortunate, or unfortunate enough to be awarded a contract for laying a wood pipe-line should first—and this is most important—get one of the stave manufacturers or wood pipe construction firms established in the West to bid a price for doing all the pipe work. If then he should reject the lowest bid from that source, for which he will afterward be truly sorry, let the contractor make sure of a man who can organize and handle this work and who has had experience in laying different kinds of pipe under varying conditions, that is, pressure lines, laid in locations that are not favorable to wood pipe. At any rate the experienced pipe constructor should first be consulted, and by doing so the contractor who may be tempted to bid on work of this kind will often be protected against heavy loss."

Wire-Wound Pipe.

Wire-wound pipe is made into convenient lengths, generally from 6 feet to 20 feet. Each joint is complete in itself and is provided with a suitable coupling. The internal diameter is maintained uniform, preserving the fullest efficiency of the pipe. The staves are of selected lumber, and milled with great precision, so that when assembled and wound, the pipe is a piece of perfect workmanship. The wire is wound around the pipe under heavy tension by a properly regulated mechanical device. The size of the wire and the spacing of the same are determined by the size of the pipe and by the pressure to which the pipe is to be subjected.



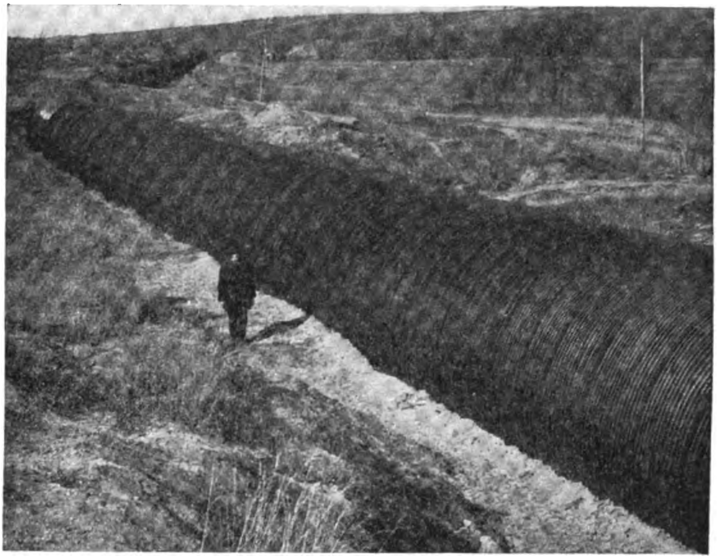
SIZES—Wire-wound pipe is manufactured in standard sizes of 2, 3, 4, 5, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30 and 32 inches, inside diameter.

HEADS—Wire-wound pipe is regularly manufactured to serve under heads of 50, 100, 150, 200, 250, 300, 350, and 400 feet. These heads in feet approximate the following pressures in pounds per square inch: 22, 43, 65, 87, 108, 152, and 173 pounds. Pipe designed for higher heads can be furnished, if required.

COUPLINGS—Inserted joint is made by carefully turning a tenon on one end and a mortise on the other end of each length of pipe, insuring a tight fit when properly driven together. It serves its purpose perfectly and commends itself for its adaptability and low cost.

Reinforced inserted joint is used on pipe 14 inches in diameter, and larger, for heads up to 100 feet. One or more steel bands, with nuts and washers, is fitted around the joint, and is finally tightened after the pipe is laid in place and driven up. This type of joint has all the advantages of the plain inserted joint in the smaller pipe, and is given the required strength and tightness of fit by the reinforcing bands.

Wire-bound collar is made in the same manner as pipe but is of greater diameter, and the wire banding is spaced much closer than on the pipe with which it is to serve. Tenons are formed on the pipe ends, to correspond with the inside diameter of the coupling. The pipe is driven into the collar and the swelling of the wood, and after water is turned into the pipe-lines makes a very tight coupling.



Continuous-Stave Pipe.

Continuous-wood-stave pipe is used in diameters from 16 inches up (the largest pipe yet constructed being 168 inches—14 feet—inside diameter.)

The staves are so milled that when assembled they form the size of the pipe desired. In building up the pipe, staves are laid side by side so that the end joints are broken. Each stave is butted against the one immediately preceding it, while saw kerfs or slits at the ends receive a thin metal tongue, thus making the stave continuous without any joint in the pipe. The smooth internal walls and the absence of joints in continuous-stave wood pipe combine to make the carrying capacity of this pipe considerably greater than that of any other type. The staves are held firmly in place by steel rods or bands tightly cinched until every stave is firmly seated. The pressure under which the pipe is to serve, and the size of the pipe, determine the diameter of the bands and spacing of same.

CAST IRON FITTINGS.—Machine-banded pipe can be fitted to any cast-iron fittings having "bell" or "hub" ends, but the fittings furnished by the wood pipe manufacturers from their standard patterns are to be recommended, being smooth finished in the "bell" or "hub," thereby saving labor in fitting the pipe. Fittings can be machine-threaded to connect with screwed pipe.

General Uses of Modern Wood Pipe.

It is not claimed that wood pipe is suitable for all hydraulic requirements. It has its limitations to be sure; but its range of usefulness is extremely wide. If the pipe is well made of selected materials, and is carefully laid, correctly proportioned and properly cared for, its limits of adaptability and use are sufficiently great for practically any field of requirement.

Wood pipe is now extensively used for the great serpentine line supplying water power for electric generating plants; for supply systems carrying the water from remote sources to the centers of consumption; for the distribution of such supplies in mains, laterals, and feeders; for extensive irrigation supply and distribution systems; for inverted siphons across deep gulches and canons which intercept the grades of open flumes or artificial channels; and for many other purposes.

The Sierra Nevada foothills, which in places were made up of immense deposits of gold gravel, were the scenes of bold pioneer hydraulic development, the technology of piping water being enriched and greatly extended by the classic examples of engineering evolved there by the late Hamilton Smith. Those same mountain ranges, and their northerly extensions, the Cascades, continue to be the field of active development tending almost exclusively toward the use of wood pipe.

IRRIGATION.—The use of wood pipe has made possible the economical irrigation of large tracts of fertile land in the arid regions in all parts of the world. Particularly is this demonstrated in the United States.

The enormous projects carried on by the United States Reclamation Service have shown the world the possibilities of irrigation when applied to otherwise worthless areas. Converting the deserts into veritable gardens has been made possible largely through the development of means for the economical distribution of available water supplies.

Open ditches or canals have in the past played conspicuous parts in the distribution systems. The necessity for maintaining a grade-line, and the resultant difficulties encountered in the use of ditches and canals, has led to the adoption of closed conduits, the latter permitting greater latitude in the choice of location, eliminating the necessity for maintenance of grade and also the conservation of tillable areas by placing such conduits beneath the surface, or in such locations as to avoid the use of good land for right-of-way. The cost of maintaining open ditches or canals is always high, and together with the loss of water through seepage and evaporation offers serious objections to this type of supply and distribution system.

Wood-stave pipe-lines are in service on almost all irrigation projects today, either large or small, and in a variety of sizes, depending on the requirements, ranging from the small wire-wound pipe having a diameter of a few inches, up to the gigantic continuous-stave pipe-lines measuring several feet in diameter.

Wood pipe has reduced irrigation water supply and distribution to a science, a fact easily substantiated by the experience of the United States Reclamation Service. In Bulletin No 376 of the U. S. Department of Agriculture, we find the following statement:

> "The present economic importance of stave pipe in this country, which arises from its adaption to so many diverse uses, its wide range of capacities, the ease with which it can be laid on rough ground, and its cheapness when compared with other pressure pipes, has led this department to investigate and report upon its merits."

HYDRO-ELECTRIC POWER DEVELOPMENT.—The development of hydro-electric power has been very marked during the last decade and the possibilities for further development are almost unlimited. In 1919 in the United States only approximately 9% of the total power used was produced by water. Of this amount more than 25% was developed during the 5 years, 1912 to 1917.

The important part played by wood-stave pipe in this rapid progress is recognized by all. The pipe manufacturers of the Pacific Coast have intalled pipe-lines all over the United States, the greatest power consuming districts of the New England States and the States bordering on the Great Lakes getting by far the greater part of the installations. These remarkable installations of continuous-stave pipe, whose lengths are measured in miles, and whose inside diameter runs as high as 12 feet, mark the beginning of a new era in power development.

In the West, the hydro-electric installations, while not so numerous, are in some instances even larger than those in use in the East and the Great Lakes districts. The electric trains of the Chicago, Milwaukee & St. Paul Railway are operated in Montana with power developed by a plant using a wood-stave pipe 14 feet in diameter.

Mention of these large size pipe-lines bring to mind the possibilities for power development on a large scale. Many power plants are in operation today where smaller pipe is used even as small as 4 inches in diameter.

HYDRAULIC OPERATIONS AND SLUICING.—Wood pipe is used extensively for hydraulic and sluicing operations; in connection with regrading operations; in connection with mining, washing gravel for gold or other precious metals, or handling the tailings. The scouring effect of sand and gravel when transported through wood pipe is less than in pipe of any other material.

SEWAGE DISPOSAL AND DRAINAGE.—Wood pipe is used quite extensively for outfall sewers and drainage purposes. It can be laid over soft, marshy ground without expensive foundations. An installation was recently made in San Francisco, where the pipe, because of its light weight, was suspended from the substructure of one of the city's piers, the outer end of the pipe-line being submerged below mean low tide. The city of Seattle has just completed the construction of an outfall sewer 60 inches in diameter across a peat bog where the surface crust was so thin in spots that it would not support a man's weight.

The manufacturers of wood pipe, using Douglas fir lumber for staves, while wisely recommending their product for those purposes for which its wide range of adaptability and suitability has been proved, have ever been alert to extend that range and to remove limitations placed on its use as far as possible.

For a great many years lumber treated with coal-tar creosote has been used for various purposes, many of which called for service under the most adverse conditions. This experience led these wood pipe manufacturers and the creosoting companies, located in the Northwest to develop a special process of creosote treatment adapted to pipe staves. The development of this special process, and the successful manufacture of creosoted staves has extended the field of Douglas fir wood pipe to a very marked degree.

After making a careful study of the requirements and a comprehensive set of tests, a special process of treatment for fir pipe staves has been developed. By this process the staves are made immune from attack, under all conditions, by decay-destroying fungi. The process has been so perfected that the treated staves retain all the strength of the natural wood, the tendency to swell and shrink has been reduced, and still the stave, although milled to exact dimensions before treatment, is unaffected in shape or size.

CREOSOTED WOOD-PIPE IN USE 28 YEARS—The Southern Pacific Railway Company has found that creosoted-wood pipe culverts put in place in 1892 are still free from decay, and the wood is in perfect condition. The conditions under which pipe must serve when used as culverts are the most severe possible.

THE PRESIDENT: We will call on Mr. Horrocks for his paper on the "Creosote Treatment for Douglas Fir Pipe Staves."

MR. H. E. HORROCKS: Mr. President and Gentlemen, you have seen the slides illustrating and describing the use of wood-stave pipe and some of the illustrations and quite a good deal of talk was devoted to the creosoted product.

I represent, when I am away from here, a company that has probably done most of the creosoting of wood-stave pipe on the Pacific Coast. Consequently, I am more or less familiar with it. The paper that I have prepared will be published and available in the PROCEEDINGS probably. It is short. I will read it, and if there are any questions I shall be glad to answer them if I can do so.

CREOSOTE TREATMENT FOR DOUGLAS FIR PIPE STAVES.

By H. E. Horrocks.

The story of the wood-stave pipe, giving the history of its development from the first crude form of a log with a hole burned lengthwise through it to the present skillfully designed types of machine-banded and continuous stave conduits, ranging from 2 inches to many feet in diameter and built up of many individual staves, each accurately machined to take its place in the assembled whole, has been told in another paper presented to this convention.

Decades of service have demonstrated the value of wood-stave pipe as a conduit; its great carrying capacity, ease of construction, adaptability to natural contour of country traversed, and of extremes of temperature, etc.

The one great drawback to its use, under certain conditions, has been that, made of wood, it was subject to decay long before its limit of usefulness had been reached mechanically.

The natural solution of this difficulty is, of course, preservative treatment. For a long time it was believed that from such treatment would naturally follow pollution of water passing through the pipe. Records were available of creosoted wood-pipe culvert construction to prove creosoted staves entirely satisfactory for pipe construction Some careful tests were made at the University of Washington, which conclusively proved no contamination, either by odor or taste, occurred to water flowing through wood pipe built of carefully creosoted staves. I may add that at the plant of the Pacific Creosoting Company water for domestic purposes is stored in a creosoted Douglas fir-stave tank, and also that all the boiler water passes through such a tank.

Finally, the Pacific Creosoting Company succeeded in convincing a large irrigating district near Wanatchee, Wash., of the value of creosoted-stave pipe; sold and supplied them with material for the construction of a continuous stave pipe-line 60 inches in diameter and about 8,000 feet long. This job went together perfectly, and from the first day of use no objection whatever was found with the water for either domestic or irrigation purposes.

That was the beginning of a very wide use of creosoted-wood stave pipe for conditions of head insufficient to insure fiber saturation of the wood at all times.

In the irrigation districts of the West particularly, this product has been of great value. In most of these areas the ditches, flumes and distributing systems do not carry water during the winter or non-crop season of the year. Naturally such intermittent service would furnish ideal conditions for rapid decay of any wood used in the construction. The early construction was entirely with untreated wood, since money for any but the cheapest work was not available in getting the land opened up and in crop. It followed that in a very few years this early work failed from natural decay and called for very heavy repairs or permanent renewal. The wood pipe had justified itself in every other way, and since means were found for protection against decay it is now being used in ever-increasing quantities.

The proper treatment of wood for stave pipe is a matter of considerable importance, the principal ends to be aimed at being:

Adequately protecting the wood from decay.

Freedom of the stave from shrinking or distortion from its section and contour when machined.

Minimum of contamination of water flowing through the pipe.

Wood must retain its original strength and elasticity.

No deposit left on the stave after treatment.

It was found that, both for machine-banded and continuous-stave pipe, the staves must be treated before assembling. Attempts were made to treat small sizes of completed machine-banded pipe, but the heat and handling invariably loosened the wires, making the pipe useless.

The stave stock must be very thoroughly air or kiln dried in the rough, then machined to its finished shape before treatment. Being well dried, it is ready to receive creosote without pre-seasoning in the retorts. This insures against loss of strength or elasticity, against shrinkage, and with careful stowing on retort trams, against distortion.

For adequate protection against decay it is not necessary that the creosote penetration be very deep, since no further machining, framing or cuts for fastenings that might open up untreated wood, are necessary.

A through and through penetration would be highly undesirable. The untreated, but thoroughly dry wood in interior of the stave very readily absorbs moisture, rapidly expands, and, in this way insures a tight conduit. We consider ¼ inch penetration from all surfaces a very satisfactory treatment.

Accumulation of pitch or sediment on surfaces or edges of the staves would contribute to contamination of the water. Such accumulations, particularly on the edges, would also seriously interfere with close and accurate laying up of the pipe, increase the diameter of the pipe, and cause unequal bearing between staves, making water tightness very difficult to accomplish.

If much free oil appears on surface of staves, even though entirely liquid, water flowing through the pipe will very likely be contaminated for some time. To overcome these objections we use a straight distillate creosote for stave treatment.

Our method of treatment is by the Empty-Cell process, using about 50 pounds initial air pressure, following the creosote pressure period with several minutes re-heating at about 25° F. in excess of any previous temperatures, then a vacuum of not less than 20 inches, maintained from 30 minutes to 1 hour. By this process we obtain very satisfactory creosote penetration, and the staves come out thoroughly clean and so dry as to scarcely soil one's hand when rubbed over them.

THE PRESIDENT: Gentlemen, would you like to ask Mr. Horrocks some questions?

How much does it add to the cost of the process?

MR. H. E. HORROCKS: Well, the cost advance of the treatment during the past year was very little, and probably not over 50% through the extreme advance during the war. Now, the percentage, however, of addition to the cost of the untreated finished stave has probably been very much greater than that. This percentage and variation of cost have been governed by two elements, the increased cost of creosoting, and the increased cost of lumber. Lumber has increased much more rapidly in cost than creosoting. Consequently, as a matter of fact, the more lumber costs increase, the greater the economy in treating the material.

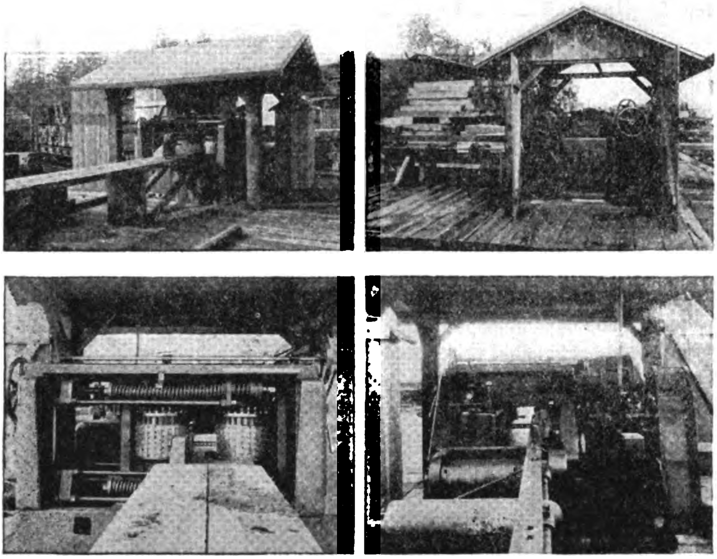
THE PRESIDENT: Is there any further discussion? If not, we will ask Mr. Taylor to present Mr. Rawson's paper on Fir Ties with particular reference to perforation.

REPORT OF COMMITTEE NO. 5-1-1—FIR TIES.

To the Members of the American Wood-Preservers' Association:

On March 27, 1920, your sub-committee received instructions to "Report recent developments in the treatment of fir ties." The last of July a meeting was called to discuss the work, and it was brought out at this time, that none of the commercial plants had made any great changes in their treatment of fir ties.

With the installation of a perforating machine at the St. Helens Creosoting Company's plant at St. Helens, Oregon, it was felt that some new developments were about to take place. The question of carrying on some tests with perforated ties was discussed, and later it was arranged to do some cooperative work with the Forest Service, West Coast Lumbermen's Association and the St. Helens Creosoting Company. The object was to study the effect of perforating on the seasoning, penetration of creosote, and the physical properties of fir ties and timbers. The Santa Fe Railway was about to carry on a series of tests, and it was hoped that some of the data could be included in this report.

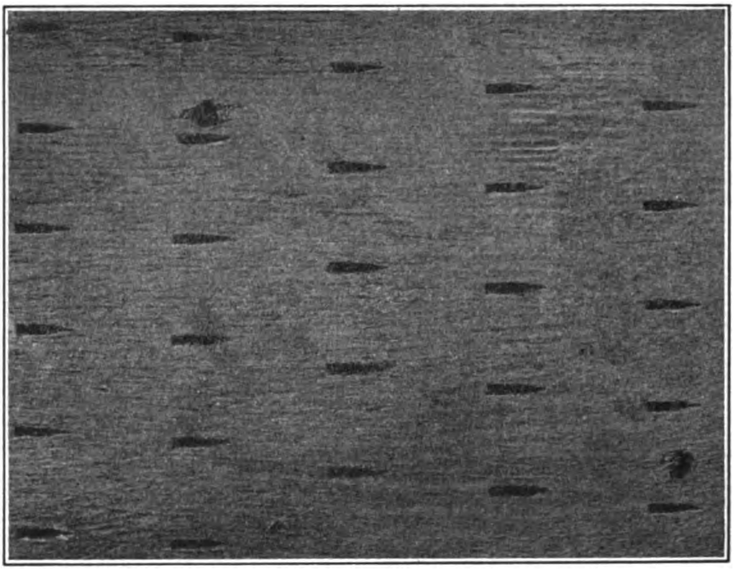


Perforating Machine, St. Helens, Oregon.

In this program for cooperative work it was arranged to have the St. Helens Creosoting Company prepare the timbers and treat them, and the West Coast Lumbermen's Association was to take the timbers so prepared and have them tested at the Seattle Timber Testing Laboratory of the Forest Service at the University of Washington, Seattle, Wash. After the tests had been made the results were to be sent to the Forests Products Laboratory, Madison, Wis., for further analysis and preparation of the report.

The working plan for these tests was received the last of October, and on November 1, Mr. C. W. Zimmerman, representing the Forest Service, and Mr. R. H. Rawson of Committee 5-1-1, selected test pieces along the lines set forth in the working plan at the St. Helens Lumber Company's mill at St. Helens, Oregon.

The method of selecting these timbers will be fully covered when the complete report is made, or it may be appended to this report for your information. Briefly, 10 sets of timbers, 8½ ins. x 9 ins. x 10 ft., with 6 timbers to set, making 60 timbers in all, were selected. Three out of each set, or 30 timbers, were grouped for testing immediately and the other half were to bet set aside for air-seasoning and subsequent testing. All of the pieces were resawn, however, in order to secure the control piece from each piece, 8½ ins. x 9 ins. x 10 ft., sized to 4 ins. x 8 ins. x 10 ft., and the pieces to be perforated were set aside to be run through the machine. One of the 4 ins. x 8 ins. x 10 ft. from each of the 3 8½ ins. x 9 ins. x 10 ft., in the group for immediate testing, was set aside as a green control piece to be tested without perforating or treating. One of the remaining 4 ins. x 8 ins. x 10 ft. sticks, matching the control stick, was to be perforated and tested, one perforated, treated and tested, and the third treated and tested.



Perforations Made With Greenlee Machine.

All of the test sticks, whether they were to be immediately treated or air-seasoned and treated later, were perforated at the same time. It was necessary to run the sticks through in pairs, as it was found that the machine would not perforate material as small as 4 ins. x 8 inches.

The sticks due for treating at this time were taken to the experimental plant of the St. Helens Creosoting Company and carefully weighed before placing in the retort.

All the pieces that were not placed in an open pile for air-seasoning and subsequent treating and testing, together with the pieces that had been treated, were shipped to the Seattle Timber Testing Laboratory of the Forest Service at the University of Washington, Seattle, Wash., where the tests, as outlined in the working plan, were made. As mentioned before, the data from these tests will be sent to the Forest Products Laboratory, Madison, Wis., where they will be further analyzed, and the report prepared. When this report is complete, it should include the working plan which covers the selection of material and tests carried out, and the treating records of the St. Helens Creosoting Company's plant.

In treating the test sticks practically the same temperatures, pressure and absorption were used, as had been carried in the treatment of ties commercially.

It is obvious that a complete report cannot be made until the second group of test sticks has passed through the seasoning period and have been tested.

Since starting the work as outlined above, your Committee has received a working plan from the Forest Products Laboratory, covering tests to show the influence of perforations on checking of Douglas fir. This work and the report not completed on the strength of perforated fir ties can be taken up by next year's Committee.

R. H. RAWSON, *Chairman.*

MR. C. M. TAYLOR: All of this report Committee No. 5-1—1, Fir Ties, is submitted as a personal contribution by Mr. Rawson, Chairman of that Committee. It is not possible at this time to go into all the details in connection with these tests. The Greenlee machine did not arrive as soon as they expected at St. Helens, and consequently, this work is not as yet complete. As you will see from the report there are cooperative tests now being conducted in which the American Wood-Preservers' Association, United States Forest Service and the West Coast Lumbermen's Association are cooperating on the question of the effect on strength of fir ties and lumber when they are processed by this machine. The report made last year by Mr. Blake covers thoroughly the history in connec-

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Note: This report was made by the chairman of the sub-committee, and it could not be approved by the members of the committee in time to insure its printing.

tion with this machine, and Mr. Edwards of the Greenlee Company will this afternoon present with lantern slides a report on the history and development of layouts for doing this work.

The main point in connection with this process is to get a better penetration of the oil into all surfaces of the fir timber. You will remember that at St. Helens they showed you samples that had been processed, and you were able to see clearly that timber that had been through this machine showed a much more even penetration of the creosote oil. The fir ties without being processed absorb too much oil in the ends and not enough on their wearing surfaces. It was with this idea of a more even penetration that this proceeding was developed. A photograph in this report shows the incisions made by this machine, and it has developed a new method whereby Douglas fir can be satisfactorily and thoroughly treated.

The only question that arises in the minds of engineers is the effect on the strength of ties and timber, and as explained in this report this work is now being conducted in conjunction with the Forest Service, and we hope that early this year there will be a special bulletin issued giving results of these tests. We have made arrangements to have a special bulletin issued by the American Railway Engineering Association, giving the results.

The point is that unless we do develop a satisfactory method for getting a more even penetration on fir, we will not be able to make fir ties last as long as they should. The Pacific Coast interests are particularly interested in this development, and it is thought that eventually all fir ties, regardless of whether they are saps or all heart, will be put through some such process.

It has an additional advantage from the fact that where ties are seasoned at very dry points, such as Paradise, Montana, where we stopped en route, it was shown a good many of these fir ties seasoned checked badly. It is probable that the developments in connection with this machine will indicate that the incisions made will cause the ties and timber to season more evenly and prevent to a great extent the large checks that ensue when the ties are rapidly dried in such arid climates.

Another point that this process will develop is the fact that it will probably prevent case-hardening, which, as you all know, in the treatment of Douglas fir, is a very serious item. It is now thought by the incisions going into the wood sufficiently, case-hardening will be pretty generally eliminated.

I am sorry that we do not have this report in such shape that it can be published this year, but as in all cases where it is a new process, the strength-tests in connection with it had to be developed slowly, and we cannot allow any advance information to come out until the whole report is finished.

We all know what an active interest Mr. Blake took in this process, and it is a pity we should not in memory of him develop it to conclusion as soon as possible.

If there are any questions you would like to ask on this I would be glad to attempt to answer them.

MR. C. E. GOSLINE: I would like to inquire if it is possible to prove whether there has been any perceptible gain in time in the treating of Douglas fir with this process?

MR. C. M. TAYLOR: As far as my understanding goes, they anticipate a very considerable saving of time by the use of this process. Mr. Fairley is here, and I would like to have him answer that question.

MR. R. H. FAIRLEY: We have not taken time into consideration, and as we have not completed our experimental work it is too early in the game to make any assertion as to how much time is gained. By perforating the ties we expect to get an even distribution of oil so that the ties will have equal protection all round, and to a great extent eliminate the light spots, such as we are troubled with a great deal in Douglas fir. I think we had better wait until this afternoon when some pictures will be shown, and I will probably have more to say.

THE PRESIDENT: Any further discussion?

(Mr. Waterman then made an announcement about transportation from San Francisco to Los Angeles and from there East, and Mr. Kelly invited the members to attend a dinner and initiation of the Concatenated Order of Hoo Hoo.)

THE PRESIDENT: Gentlemen, please be prompt at 2:00 o'clock. The meeting is adjourned.

WEDNESDAY AFTERNOON SESSION

January 26, 1921

THE PRESIDENT: The meeting will come to order. We will recognize Mr. Brown.

MR. A. A. BROWN: Mr. Chairman, all the gentlemen here probably heard Dr. Kofoid last night in his very able address on the subject of the teredo and various marine borers. There are few biologists in the world who are able to do the work which Dr. Kofoid has done for us, and since this work has consumed all of his time that he has been expected to put in on research, it would be very fitting and a wise thing, I believe, for us to write a letter to the President of the University, Dr. David P. Barrows, expressing our appreciation for Dr. Kofoid's work and hoping that he might be able to continue it for another year. I would like to make the motion that this Association write such a letter to the President of the University.

MR. CARL G. CRAWFORD: Second the motion.

THE PRESIDENT: Gentlemen, it has been regularly moved and seconded that our Association direct a letter to the President of the University advising him of our appreciation of the work which has been done by Professor Kofoid. I think it is hardly necessary to say that we all feel the same about the quality of the work which Professor Kofoid has done. He is one of the few men in the world fitted to do what he has accomplished.

Are you ready for the question? All in favor respond by saying "aye"; contrary, same sign; it is so ordered. The Secretary will write the letter as proposed by Mr. Brown.

"Experiments with Butt-Treated Poles in California," by Mr. P. R. Hicks will be briefed for us by Mr. Hunt.

EXPERIMENTS WITH BUTT-TREATED POLES IN CALIFORNIA.

By P. R. Hicks.*

In 1907 and 1908 the Forest Service in cooperation with various California electric companies, carried on a number of experiments to obtain information on the seasoning of poles and the efficiency of several preservatives and methods of butt treatment. Western red cedar, the principal species used for the larger class of poles in California, and western yellow pine poles, were used in these experiments. The western yellow pine was studied to determine whether butt-treated local timber could be satisfactorily used as a substitute for the relatively high-priced western red cedar poles, which were usually obtained from the Pacific Northwest.

It is the purpose of this article to describe briefly the treatments and the condition of the experimental treated and untreated poles after about 11 years' service

Preservative Treatment.

The western yellow pine poles were treated at Friant, Cal., early in 1908, after seasoning to about 32 lbs. per cubic foot. The seasoning period varied from 2 to 10 months depending upon the season of the year the poles were cut. About 3 or 4 months elapsed after treatment before these poles were set. The western red cedar poles were obtained from northwestern Washington and were treated at Wilmington, Cal., in 1907 and 1908, after a seasoning period varying from about 3 to 9 months in Southern California. These poles were about half-seasoned upon arrival at Wilmington. From 6 months to a year elapsed after treatment until the cedar poles were set.

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*Engineer in Forest Products, Forest Products Laboratory, Madison, Wis.

The average absorption and penetration of the preservatives are given in Table 1. The creosote and carbolineum used in the brush treatments were applied from the butt end to a height of 7 feet at a temperature of from 170° F. to 200° F. The second coat was applied several days after the first coat.

TABLE 1.—AVERAGE ABSORPTION AND PENETRATION OF PRESERVATIVES.

Preservative used sold as	Treatment.	Western red cedar.		Western yellow pine.	
		Absorption.	Penetration.	Absorption.	Penetration.
		Lbs. per pole.	Inches.	Lbs. per pole.	Inches.
Coal-tar cresote.*	Open tank.	31.0	.56	78.0	3.0
Coal-tar creosote.*	Brush, 2 coats.	6.5	⅛	3.8	⅛
Carbolineum America.	Brush, 2 coats.	5.3	⅛	5.0	3/16
Crude oil.	Open tank.	10.0	None.	54.0	2.0
Zinc chloride.	Open tank.	0.5**	Not determined.	1.25**	Complete.
Zinc Creosote.	Open tank.	.25 lb. zinc** .7 lb. creo **	Not determined.	----------	----------

*Analysis showed this preservative to be more like a water-gas-tar creosote than a coal-tar creosote.

**Pounds of dry zinc chloride per cubic foot.

***Per cubic foot.

It will be noted that the absorption and penetration obtained by brush treating western yellow pine with carbolineum was a trifle more than that obtained with creosote. There is evidently no reason why a deeper penetration should be obtained with carbolineum, and the relatively small difference is probably on account of the condition of seasoning of the poles where penetration determinations were made, because of possible errors in measuring such small penetrations, or on account of a little larger absorption. In the brush treatments on western red cedar poles the same penetration was obtained with carbolineum as with creosote, although the absorption of creosote was a little greater.

In the brush treatments the absorption, and possibly the penetration, varied considerably according to the stage of seasoning of the wood, the effect of recent rains, the humidity of the atmosphere, and the intent of the workmen applying the preservatives. It was difficult also to protect the interior of the season checks by the brush method. The data obtained on the brush treating of western red cedar poles indicate that this species should preferably be seasoned to at least 24 lbs. per cubic foot before applying the preservatives, in order to obtain the maximum penetration and absorption. In this experiment, this required an average seasoning period of about 5 1/3 months in the climate of Southern California.

Butt treatments by the open-tank process were conducted with creosote, zinc chloride, crude oil, and a combination of zinc chloride and creosote as preservatives. The poles were treated for a distance of 7 feet from the butt end. As would be expected a greater absorption and penetration, and hence a more effective treatment, was obtained by the open-tank than with the brush method.

Greater absorptions and penetrations of all preservatives were obtained in the western yellow pine than in the cedar poles treated by the open-tank method. In treating the pine poles with creosote the preservative was kept at from 170° F. to 200° F. during the hot bath, while a hot bath of about 212° F. was used for the treatment of western red cedar. The cold bath was usually carried on by allowing the poles to cool in the preservative used for the hot bath. Varying periods were necessary for the hot and cold baths, depending upon the dryness of the poles.

The results obtained in the treatment of poles by the open-tank process indicated that western red cedar poles should be seasoned to at least 25 lbs. per cubic foot before treatment which required 2 to 8 months in this experiment depending upon the season the poles arrived in Southern California. Greater absorptions and penetrations were obtained after seasoning to 23 lbs. per cubic foot, which required an additional month to season.

The pine poles were treated much more readily than cedar. Only the sapwood of western red cedar, which is usually from ½ to 1 inch in depth, could be treated with creosote by means of the open-tank process, whereas in the pine a penetration of 3 inches was easily obtained.

Western red cedar could not be successfully impregnated with crude oil by the open-tank method, although a satisfactory treatment was obtained on the western yellow pine poles.

Satisfactory absorptions were obtained in the open-tank treatment of the pine and cedar poles with zinc chloride, although the pine absorbed more of the preservative, with a probable greater penetration, than the cedar poles.

The duration and the temperature of the hot and cold baths were varied as in the treatments with creosote. Western red cedar poles seasoned to only 31 lbs. per cubic foot could be successfully treated with zinc chloride compared with 25 lbs. per cubic foot, which was found desirable for the successful treatments with creosote. The open-tank treatments with creosote and zinc chloride could be used only on the cedar poles after being seasoned to at least 25 lbs. per cubic foot. Poles treated by this method were usually held in a bath of creosote at 212° F. for an hour or more, then plunged into a solution of zinc chloride. No treatments of this kind were given any of the pine poles.

Preservatives.

The creosote used for the treatment of these poles was purchased as coal-tar creosote. Six samples of this creosote, taken at different times, were analyzed, and in all cases over 40% of the oil distilled below 235° C. This would indicate that the creosote would not be accepted today as Grade 3 A. W. P. A. creosote oil for ties and structural timber. Tests such as the index of refraction, specific gravity, and sulphonation residues of the fractions all indicated that this preservative was more nearly like a water-gas-tar creosote than a coal-tar creosote. The analyses are given in Table 2.

TABLE 2.—ANALYSES OF CREOSOTE.

	Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.	Sample No. 5.	Sample No. 6.
Specific gravity at 60° C.	1.0156	1.0223	1.0322	-------	-------	-------
Specific gravity at 50° C.	-------	-------	-------	1.0155	1.0240	1.0205
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Distillate up to 205° C.	17.6	8.3	3.0	15.8	9.9	11.1
" 205° C. to 255° C.	49.1	49.1	49.3	55.7	57.9	56.8
" 255° C. to 295° C.	14.0	13.4	14.2	11.4	12.6	12.7
" 295° C. to 320° C.	6.5	8.0	6.9	4.8	5.0	6.6
Residue	12.4	21.1	19.4	11.6	11.8	12.0
Loss	0.4	0.1	0.4	0.7	0.2	0.8

NOTE.—Analyses calculated to water-free basis. Western red cedar poles treated with creosote similar to samples 1, 2 and 3. The pine poles were treated with creosote similar to samples 4, 5 and 6.

The carbolineum used on these experimental poles was purchased from the C. A. Manufacturing Company, Austin, Tex., as Carbolineum America. A sample taken for analysis was too small to be analyzed. Following is an analysis made about the same time according to the standard methods of the American Telephone and Telegraph Company on another sample of this carbolineum procured from the manufacturer:

ANALYSES OF CARBOLINEUM.

	Required by A. T. & T. Co. Specifications.	Found.
Specific gravity at 17° C	1.1 to 1.4	1.12
Flash point	Not less than 121° C.	128° C.
Burning point	" " " 163° C.	165° C.
Mineral matter	Not more than .05%	.045%
Distillates:		
Below 235.5° C.	" " " 2%	.12%
235.5° C. to 315° C.	" " " 15%	27.58%
Residue	" " " 90%	71.85%
Loss	" " " .5%	.45%
Tar acids	" " " .5%	.33%
Solids	No separation 35° F.–40° F.	None

It is seen from the above results that this oil compares very favorably with the specifications for carbolineum of the American Telephone and Telegraph Company, being fully up to the standard in all tests but one, namely, that portion distilled between 235.5° C. and 315° C.

Method of Setting.

No regular procedure was followed in setting the experimental poles, although treated and untreated poles were alternated as often as possible in the various lines.

Method of Inspection.

The original circumference of the poles at the point of greatest decay, generally at or just below the ground line, was determined by measurement shortly after the poles were set.

The first step in the inspection was to remove the soil from the butt of each pole to a depth of about 1 foot.

Each pole was hit in several places near the ground line with the blunt end of a hand ax to determine by sound if the pole was hollow. If the pole sounded hollow, increment borings were made as often as necessary to determine the size and location of the "hollow" and the holes were carefully plugged with creosoted plugs.

Decayed portions of the pole, or portions destroyed by insects, were carefully removed with a chisel or hand ax, and the circumference measured at the point of greatest decay, which was usually found to be at or near the point selected for the first measurement. In this manner the loss in circumference of each pole was readily determined. Corrections to this circumference were made for decayed pockets or checks and hollow centers.

As a check on the location of each measurement, and to allow for occasional ground line changes, a small copper or zinc nail was usually driven in the pole butt 12 inches above the original measurement. The soil was carefully replaced around the pole butts after the inspection was completed.

The representative of the Forest Products Laboratory was assisted by one or more members of the cooperating companies during each inspection.

Condition of Experimental Poles.

WESTERN YELLOW PINE POLES.—The 40-foot experimental western yellow pine poles set in 1908 in the Stokes Mountain Line of San Joaquin Light and Power Corporation, near Fresno, Cal., were cut, peeled and seasoned during 1906 and 1907 in Madera County, California. The treating experiments were carried on early in 1908. Results obtained with these treated and untreated experimental pine poles are given in Table 3, and penetration and absorption of the preservatives in Table 1.

The average life of the pine poles butt-treated with creosote by the open-tank process was 8.4 years, compared with 3.8 years for the untreated poles. The relatively short life of these treated poles was not on account of failure of the treatment in the butts, but was caused by decay in the untreated tops.

About one half of the poles butt-treated with zinc chloride were, however, removed on account of decay in the treated butts.

Approximately one-third of the poles butt-treated with crude oil by the open-tank method failed on account of decay in the treated butts. While the average life of the poles butt-treated with zinc chloride and those treated with crude oil was about the same, no definite conclusions can be drawn as to the relative merits of zinc chloride and crude oil, on account of the comparatively small number of poles in the summary and the large number of failures in the untreated tops.

There was no appreciable difference in the relative durability of the pine poles brush-treated with creosote and with carbolineum. The small difference in favor of the carbolineum is not sufficient to have much weight, especially in view of the results obtained in other similar experiments.

TABLE 3.—CONDITION OF WESTERN YELLOW PINE POLES, SET IN 1908 IN THE STOKES MOUNTAIN LINE OF THE SAN JOAQUIN LIGHT AND POWER CORPORATION NEAR FRESNO, CAL. INSPECTION 1911 TO 1917, AFTER 8 TO 9 YEARS' SERVICE.

Year inspected	Treatment (Butts only)	Total No. Set	Eliminated from test	No. in experiment	Butts: Sound: Tops O. K.: No.	%	Tops decayed still in service: No.	%	Removed on account of decayed tops: No.	%	Decayed: Slight: No.	%	Removed: No.	%	Treated wood sound but heartwood decayed: No.	%	Average life	1917 Remarks
1911	Creosote - Open Tank	238	1	237	237	100												Failure due to decay in untreated tops
1912		238	3	235	231	98.3					4	1.7						
1913		238	6	232	228	98.3					4	1.7						
1914		238	11	227	224	98.6			1	0.5	2	0.9						
1915		238	11	227	199	87.6			28	12.4								
1916		238	19	219	117	53.4			102	46.6								
1917		238	21	217	26	12.0	54	24.9	131	60.4	2	0.9			4	1.8	8.4* years	
1912	Zinc chloride Open Tank	42		42	31	73.8					5	11.9	6	14.3				About one-half of removals due to decay in treated butts
1913		42		42	31	73.8					3	7.2	8	19.0				
1914		42		42	21	50.0			1	2.4	4	9.5	16	38.1				
1915		42		42	21	50.0			2	4.7	3	7.2	16	38.1				
1916		42		42	16	38.1			7	16.7			19	45.2				
1917		42		42	--	---	3	7.2	7	16.7	6	14.3	22	52.3	4	9.5	7.2* years	
1912	Crude oil - Open Tank	13		13	9	69.2					2	15.4	2	15.4				Approximately one-third of removals due to decay in butts and remainder due to decayed tops
1913		13		13	9	69.2					2	15.4	2	15.4				
1914		13		13	9	69.2			1	7.6			3	23.1				
1915		13		13	--	---	5	38.4	4	30.8			4	30.8				
1916		13		13	--	---	4	30.8	5	38.4			4	30.8				
1917		13		13	--	---	4	30.8	5	38.4			4	30.8			7.1* years	
1912	Carbolineum - Brush	44		44	2	4.5					24	54.5	18	41.0				Removals due to decay in treated butts
1913		44		44	2	4.5					24	54.5	18	41.0				
1914		44		44	2	4.5			1	2.3	3	6.8	38	86.4				
1915		44		44	2	4.5			1	2.3	1	2.3	40	90.9				
1916		44		44	1	2.3			1	2.3			42	95.4				
1917		44		44	--	---			1	2.3			43	97.7			5.4 years	
1911	Creosote - Brush	47		47							45	95.8	2	4.2				Removals due to decay in treated butts
1912		47		47	4	8.5					18	38.3	25	53.2				
1913		47		47	4	8.5					18	38.3	25	53.2				
1914		47	1	46	1	2.2			1	2.2	3	6.5	41	89.1				
1915		47	1	46	1	2.2			3	6.5			42	91.3				
1916		47	1	46	1	2.2			3	6.5			42	91.3				
1917		47	1	46	--	---			3	6.5			43	93.5			5 years	
1910	Untreated	12									7	58.3	5	41.7				Removals due to decayed butts
1911		12									7	58.3	5	41.7				
1912		12									4	34.0	8	66.0				
1913		12									4	34.0	8	66.0				
1914		12											12	100.0			3.8 years	

*Estimated that remaining poles would be serviceable for one more year.

These experiments demonstrated that butt-treated western yellow pine poles cannot be successfully used in Southern California, in comparison with untreated or similarly treated western red cedar poles, on account of failure of the untreated tops. If this species is to be used for poles in Southern California, the entire pole should be treated, preferably with creosote.

WESTERN RED CEDAR POLES.—The butt-treated and untreated experimental 35-foot and 40-foot western red cedar poles were placed during 1907, 1908, and 1909, in the vicinity of Los Angeles, in the lines of the Pacific Electric Railway, Southern California Edison Company, Los Angeles Gas and Electric Company, U. S. Long Distance Telephone and Telegraph Company, and the Southern California Telephone Company. Inspections of these poles were made in the fall of 1910, 1911, 1912, 1913, 1916, and in January, 1920. For convenience in presenting the 1920 inspection data, Table 4, and Fig. 1 have been prepared. In calculating the average loss in circumference at the point of greatest decay (usually at or near the ground line) a replacement circumference of 24 inches was assumed for the few poles already removed.

GENERAL CONCLUSIONS

The depth of penetration of the preservative appears to exercise the controlling influence on the durability of butt-treated western red cedar poles. An average penetration of 0.56 inch was obtained in the open-tank treatments with creosote.

Out of a total of 375 poles given this treatment, 349, or 93.1%, were still sound, and 26, or 9.6% were partly decayed after 11 years' service. The average penetration of the 26 poles which were partly decayed was only 0.28 inch. The decay was caused principally on account of checks through the comparatively thin treated part of the pole, and occurred in most cases simply as a decayed pocket, while the rest of the butt was sound. A few small decayed pockets were found also under thin strips of bark which prevented the penetration of creosote during treatment.

Western red cedar poles could not be satisfactorily butt-treated with creosote by the open-tank or the brush methods unless seasoned to at least 25 lbs. per cubic foot. Better penetrations were obtained when they were seasoned to 23 pounds.

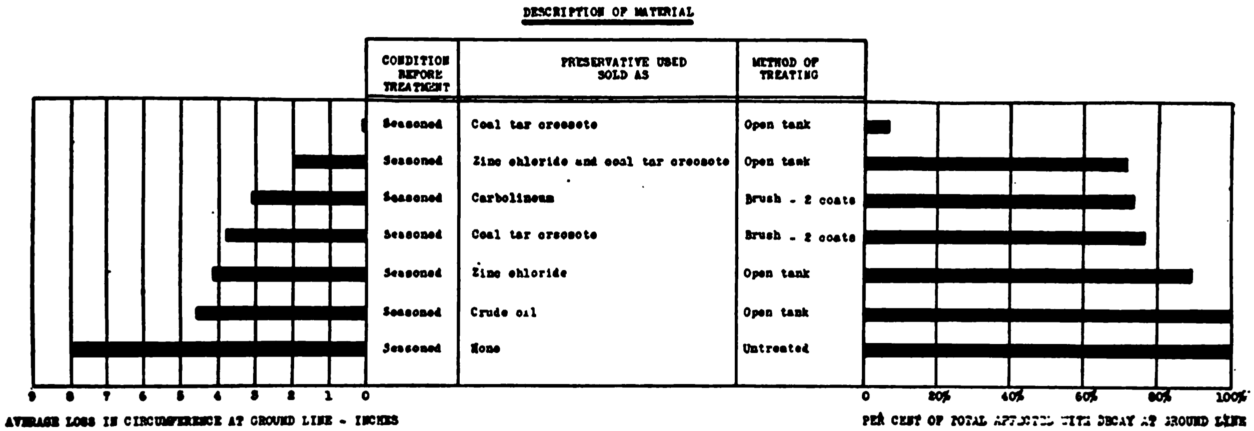
The poles treated in an open-tank with zinc chloride and creosote were in somewhat better condition than those brush-treated with creosote or with carbolineum. The brush-treated cedar poles were in better condition than those treated with zinc chloride by the open-tank process.

TABLE 4.—CONDITION OF EXPERIMENTAL WESTERN RED CEDAR POLES SET IN THE VICINITY OF LOS ANGELES, CAL., AFTER 11 YEARS' SERVICE. RESULTS OF 1920 INSPECTION.

Treatment	No. of poles		Sound		Partially decayed		Removed on account of decay		*Eliminated from test	Average original circumference	Average loss in circumference		Loss in circumference per cent per year (weighted average)
	In test	In summary	No.	Per Cent	No.	Per Cent	No.	Per Cent			Inches	Per Cent	
Creosote - open tank	457	375	349	93.1	26	6.9	...	...	82	385	.09	.23	0.02
Zinc chloride	171	131	14	10.7	112	85.3	5	4.0	40	38.8	4.12	10.6	0.96
Zinc creosote	56	42	12	28.5	29	69.0	1	2.5	14	38.8	1.93	4.9	0.45
Crude oil	3	2	...	..	2	100.0	...	...	1	41.5	4.55	10.9	0.99
Carbolineum brush	59	53	14	26.4	37	69.8	2	3.8	6	38.2	3.08	8.1	0.74
Creosote brush	68	52	12	23.1	36	69.2	4	7.7	16	38.6	3.78	9.8	1.08
Untreated	56	51	...	..	31	60.8	20	39.2	5	38.0	7.94	20.9	2.69

*Eliminated from test due to removal for new construction without record of disposal, poles set too deep, set in cement walk or curb where it was impossible to make a careful inspection, burned, broken by accident, etc.

Fig. 1.—Condition of Experimental Western Red Cedar Poles in the Vicinity of Los Angeles, Cal., 11 Years After Placement.



As only two poles treated with crude oil were included in these experiments, no conclusions can be drawn as to the value of this treatment.

In this experiment the value of the open-tank treatment with creosote as compared to brush treatment stands out clearly. The results from the brush treatments, however, are very good, as will be seen by comparing their condition with that of the untreated poles. Undoubtedly brush treatment of cedar poles is a good investment where a better treatment is for some reason or other impractical.

In analyzing the above data, and in comparing the results obtained with treated and untreated poles in other parts of the country, it must be kept in mind that on account of climatic conditions in Southern California these experimental poles are subjected to decay throughout the entire year.

MR. GEO. M. HUNT: Mr. Chairman, this report covers a subject which is not new to this Association or to those who are interested in the preservative treatment of poles. Its object is to bring up to date information on an experiment which was started some 12 years ago in California. We have a great many service-tests under way throughout the country, and it is necessary to keep the public informed as to the progress of these experiments from time to time, hence this paper.

In Southern California the climate is such that decay can proceed during a very large portion of the year, and conditions are not the same as we have in some other parts of the country where it is cool for a long season, and decay during that time is dormant. For instance, it is not reasonable to expect that a pole in Southern California will give the same life as a pole perhaps in New York, or New England.

The western yellow pine poles were given a butt treatment with various preservatives. The butt treatments have protected the part of the poles where they were applied, but the wood above the treatment, that is, the tops of the poles, for the most part have decayed. The poles have been rendered unserviceable, not because of the failure of the treatment, but because they were not treated throughout their entire length. With the western red cedar this does not hold. The red cedar does not decay above the ground-line, and does not, therefore, appear to need treatment above the ground-line. Therefore, the cedar poles have given very satisfactory service. It shows that if you wish to use western yellow pine poles you can be safe only if you treat the entire pole. The butt treatment is not sufficient for that species.

SERVICE-TESTS OF TREATED AND UNTREATED FENCE POSTS.

By J. D. MacLean.*

A series of experiments have been conducted by the Forest Service to obtain information on the relative durability of untreated fence posts of various species and those treated by different methods and with a number of preservative oils. These experiments have, to a large extent, been conducted in cooperation with a number of State agricultural experiment stations.

Most of the posts were placed in service from 1908 to 1909, and inspections of their condition have been made at intervals since then. The object of this paper is to present the information obtained to date in these investigations, and to discuss briefly the results of the tests.

Cooperating Experiment Stations.

Much of the experimental work has been done in cooperation with the agricultural experimental stations listed below, and acknowledgment is made to the officials of these stations for their valuable assistance in making these tests:

Alabama Polytechnic Institute, Auburn, Alabama.
Iowa State College, Ames, Iowa.
Maryland Agricultural Experiment Station, College Park, Maryland.
North Louisiana Agricultural Experiment Station, Calhoun, Louisiana.
State Agricultural Experiment Station, Ft. Collins, Colo.
South Carolina Agricultural Experiment Station, Clemson College, South Carolina.
University of Minnesota, Agricultural Experiment Station, Zumbra Heights, Minnesota.

This wide distribution of the experimental posts in various parts of the country has made it possible to study the durability of a large number of species used for post material under different climatic and soil conditions.

Experiments of this nature must extend over a considerable period of time, and it is to be expected that some of the posts will be lost through changing of fence lines, and other causes. Some of the posts were treated and placed in service on farms in the vicinity of the experiment stations. However, the larger proportion were placed in use on the grounds of the experiment stations so that it has been possible to keep much more accurate records of removals and changes in the fence lines than is usually possible on farm fences.

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The posts were generally set a short time after treatment, although in a few cases they were open-piled for a year or two before they were placed in service.

Method of Making Inspections.

Each experimental post was tagged with a zinc or brass tag for identification. The inspections have been made at intervals varying from 1 to 2 years.

Posts found to be practically free from decay were classed as "sound," those which were affected with decay at the tops or butts and were still serviceable were classed as "top partly decayed" or "butt partly decayed." When the progress of decay was so advanced as to warrant early removal of the post it was classed as "top decayed" or "butt decayed." Posts which had been removed on account of decay were so recorded. When fence lines were moved posts often disappeared from the test on account of the identification tags becoming lost or through the placing of the posts in other fences where they could not be located. In some cases the posts were destroyed by causes other than decay. Those which were known to have disappeared for any of these reasons were classed as "missing."

The data given in Tables 1 to 9 inclusive are based on the number of posts found at the last inspection and on those recorded as "removed on account of decay."

Discussion of Results.

With a few exceptions, most of the posts treated at the experiment stations averaged from 5 inches to 6 inches in diameter and from 6½ feet to 7½ feet long. Most of these were treated in the round form, which is the most suitable form of post for treatment since the sapwood is more easily impregnated than the heartwood.

Where there are only a few posts of a given species, or where there are only a few in a particular treatment, too much weight should not be attached to the results.

On account of the comparatively small number of untreated posts set in these experiments it is difficult to obtain reliable figures on the average life of various species when untreated, or to compare the relative durability of treated and untreated posts. It is known, however, that when untreated, the non-durable woods used for post material have an average life varying from 2 years to 5 years, depending upon the soil conditions, location, etc.

A large proportion of the treated posts had been in service between 10 years and 12 years at the time of the last inspection. Table 1 shows the condition of the posts of each species at the various locations where they are placed in service. In this table the species are arranged alphabetically and grouped according to treatment. Table 1-a gives data on a number of experimental posts which have not been inspected recently.

Tables 2 to 9 inclusive are summaries of data given in Table 1, and show the condition of treated posts which have been in service from 10 years to 12 years. In these tables the posts are grouped according to the preservative and method of treatment employed. Posts of the non-durable woods are grouped separately from those which are commonly considered durable when untreated. The durable species include such woods as cedar, chestnut, cypress, black locust, and others fairly resistant to decay. In this classification the term "durable" applies only to the heartwood.

In addition to the posts set in cooperation with the agricultural experiment stations, Tables 1 and 1-a contain data on posts set in various other locations. The service records on these however, are for a shorter period, and the data are given for the purpose of making the records complete. On account of the shorter period of service these posts are not included in the summaries given in Tables 2 to 9 inclusive.

Alabama Polytechnic Institute, Auburn, Alabama.

The posts at this experiment station were treated with coal-tar creosote using a hot-bath-butt treatment, and a cold bath for the entire post. All the posts were open piled for about 2½ years after treatment.

About 25 of the pine and gum posts were treated shortly after heavy rains, and at the time of treatment were found to have more or less irregular penetrations. It is very probable that the poor penetration in some of these posts is responsible for their early decay. Many of the posts at this place are also under severe conditions, being covered with vines or surrounded with brush and dense undergrowth.

Iowa State College, Ames, Iowa.

All of the posts treated for this experiment station were given a butt treatment with coal-tar creosote. The larger part of these were white cedar, which with very few exceptions are still in excellent condition. Quite a number of the posts of non-durable species were destroyed by decay at the top, above the treatment. Apparently the oil became low in the tank during the treatment of some of the posts, or they were set too deeply, and these have decayed at the butt on account of the treatment not extending above the ground-line.

Maryland Agricultural Experiment Station, College Park, Md.

Posts of 19 different species were treated and set at this experiment station. The preservatives used were coal-tar creosote, crude petroleum, semi-liquid asphalt, and water-gas tar. Treatments were made with each of the three latter preservatives for the hot bath, in order to study their value as a heating medium. After treatment in the hot bath, the entire post was treated in a cold bath of coal-tar creosote. The object in using oils other than creosote in the hot bath was to investigate the possibilities of using a cheap oil for this purpose, to avoid the loss through volatilization of the more expensive creosote oil. The good results secured in these durability tests seem to indicate that both the crude petroleum and water-gas tar offer possibilities of a satisfactory substitute for creosote in the bot-bath treatment. It was found that the semi-liquid asphalt employed in these experiments was unsatisfactory, as it heated up slowly and gave considerable trouble from foaming.

North Louisiana Agricultural Experiment Station, Calhoun, La.

The posts set at this experiment station were given a hot-bath-butt treatment in coal-tar creosote followed by a cold bath treatment for the entire post. These were set at intervals between March, 1908, and March, 1910, and had been in service from 10¼ years to 12¼ years at the time of the last inspection. Prior to the time of setting, the posts were open-piled at the station.

Results of the test indicate that the bay posts are much less durable than those of the other species, although the treating records show that they received the heaviest absorption, which averaged between 8 lbs. and 9 lbs. per cubic foot. It would appear that these posts were saturated with oil at the bottom where it was of little value, and that the radial penetration was very limited. These posts have shown a tendency to check considerably, and these checks may hasten decay by exposing untreated wood.

The loblolly-pine posts are not in as good condition as the cypress or gum posts. It is stated in the report on the treatments that difficulty was experienced in removing the inner bark from these posts and that this bark interfered in securing a proper treatment.

State Agricultural Experiment Station, Ft. Collins. Colo.

The species of posts set at Ft. Collins, comprised Alpine fir, lodgepole pine, and Engleman spruce. Posts of each species were given open-tank-butt treatments and brush treatments with water-gas tar. Lodgepole pine and Engleman spruce posts were also given brush treatments with crude oil. At the last inspection all the posts had been in service 6 years.

It will be observed from the data in Table 1 that the posts given an open-tank-butt treatment with water-gas tar were in far better condition than any of the posts given a brush treatment. A comparison of the posts brush-treated with crude oil and with water-gas tar shows that only 3% of those brush-treated with crude oil are sound, and 67% are decayed or have been removed on account of decay. There are 52% of the posts brush-treated with water-gas tar which are still sound, and 12% are decayed, or have been removed on account of decay.

South Carolina Experiment Station, Clemson College, S. C.

The posts at this station were treated in August and September, 1908, and were set between January and August, 1909. It has been necessary to change the fence lines several times in some locations, and now quite a number of the posts are missing from those originally set.

A considerable amount of experimental work was done at this station to study various factors affecting treatment, and for this reason some of the posts received poor penetrations.

Both open-tank and brush treatments were made on several species with coal-tar creosote. A few posts were also charred to investigate the value of charring as a protection against decay.

University of Minnesota Agricultural Experiment Station, Zumbra Heights, Minn.

About 2,000 posts were originally treated in cooperation with this experiment station in 1908. Part of these were placed in service on the University fruit farm at Zumbra Heights, and a large number were sold for use on nearby farms. About 90% of the treated posts were split, the larger proportion being basswood and red oak. At the last inspection about 1,100 were still included in the experiment. Most of the missing posts were lost on the various farms when removals or changes were made in the fence lines.

All species in the experiment were treated with coal-tar creosote. Two of the species, basswood and red oak, were treated with water-gas tar and also with a hot bath of water-gas tar followed with a cold bath in coal-tar creosote for the entire post.

Posts of all species were treated with a cold oil bath only in coal-tar creosote to determine the effectiveness of this treatment. The best results with this method were secured in the treatment of red oak, probably on account of its open-porous nature which permitted the creosote to penetrate more thoroughly than in the other species. While this method was much less effective with the other woods, it is no doubt considerably more efficient than the brush treatment.

In 1912 a total of 135 posts of several species were given open-tank, brush, and dipping treatments with coal-tar creosote, and brush and dipping treatments with carbolineum. On account of the small number of posts of each species in a treatment, the species are all grouped in the treatments and classed as "mixed" species in Table 1.

General Conclusions.

The following general conclusions are made from the data obtained in these experiments:

(1) The durability of posts whether treated or untreated is influenced by a number of factors, such as species, method of seasoning, size of post, proportion of heartwood and sapwood, whether posts are round or split, soil conditions, and climatic conditions.

(2) Posts should be thoroughly seasoned, and all bark entirely removed before treatment.

(3) Radial penetration is of prime importance, and a good absorption is not always an indication of a satisfactory treatment. Some species, such as basswood, bay, cottonwood, poplar, and willow, appeared to take heavy absorptions, due to end penetration, but were very difficult to penetrate radially. This might result in an excessive absorption and penetration in the bottom 6 inches of the post, but very little near the ground-line, which is the most important point. Special care should, therefore, be used in the treatment of such woods to secure the best possible radial penetration at the ground-line.

(4) In order to secure the most satisfactory results both tops and butts should be treated, although the tops need not be given such a heavy treatment as the butts. It is especially important that the tops of posts of non-durable species should be treated.

The superiority of treatment of the entire post over butt treatment only is very marked in the results of the tests. Posts given a butt treatment were all set in the Northern States where the decay conditions are less severe than those in the South. However, with the exception of the durable species, there is a wide difference in the durability of posts given the butt treatment as compared with posts given both a top and butt treatment. Butt treatments are apparently more suitable for posts of the durable wood in the split form, or where they have very little sapwood. Where it is not possible to treat the entire post on account of the lack of time or equipment, a butt treatment is well warranted and will increase the life of the posts very materially.

(5) Brush treatment helped increase the life of posts, but this method of treatment is very inferior to the open-tank method.

(6) Charring posts seems to be of very little, if any, value as a protection against decay. Any checking through the charred area exposes untreated wood to the action of fungus, and efforts to increase the life of posts by this method have usually proved to be unsatisfactory.

(7) The order of merit of the non-pressure treatments employed in these experiments is as follows, beginning with the one showing the best results:

(a) Open-tank treatment of the entire post in creosote oil. Butts treated in hot bath followed by a cold oil bath for the entire post.
(b) Hot and cold-bath-butt treatment with coal-tar creosote.
(c) Cold oil bath only with coal-tar creosote.
(d) Brush treatment with coal-tar creosote.

(8) Water-gas tar apparently possesses preservative qualities, and when a suitable penetration is obtained the results will probably be satisfactory. It is necessary, however, that a water-gas tar of good quality should be selected.

(9) Crude oil by itself seems to be very unsatisfactory for post treatment on account of its low toxic value and the difficulty of obtaining a good penetration.

(10) The good results secured with the use of crude petroleum and with water-gas tar for the hot bath seem to indicate that it may be practical to substitute a cheaper oil for the heating medium when creosote is employed for the subsequent cold bath.

(11) Results of the experiments in various sections of the country show that posts decay much more rapidly in the Southern States than they do in the North where winters are longer and more severe. For this reason it is particularly essential that the entire post should be treated when it is to be used in the southern climate.

(12) The open-tank method of treatment seems to be entirely satisfactory for fence posts, provided they are properly prepared, and a suitable preservative is used.

The analyses of several oils used in these experiments are given below. These analyses were made by the Forest Service method as described in Forest Service Circular No. 112.

MARYLAND AGRICULTURAL EXPERIMENT STATION, COLLEGE PARK, MD.

Creosote (first shipment).

Specific gravity at 60° C. 1.0210

	Per cent.
Water content	1.2
Distillate up to 205° C.	12.1
" 205–255° C.	53.3
" 255–295° C.	14.0
" 295–305° C.	2.5
Residue	16.8
Loss	0.1
Total	100.0

Index of refraction values ranges from 1.5915 to 1.6227.

Creosote (second shipment).

Specific gravity at 60° C. 1.0256

	Per cent.
Water content	trace
Distillate up to 205° C.	10.4
" 205–255° C.	53.4
" 255–295° C.	13.2
" 295–320° C.	9.1
Residue	13.6
Loss	0.3
Total	100.0

Index of refraction values ranges from 1.5363 to 1.6133.

Crude oil.

Specific gravity at 60° C. 0.8991

	Per cent.
Distillate up to 205° C.	8.1
" 205–255° C.	15.7
" 255–295° C.	17.2
" 295–308° C.	6.1
Residue	52.0
Loss	0.9
Total	100.0

Index of refraction values ranges from 1.4386 to 1.4807.

Water-Gas Tar.

Specific gravity at 60° C. 1.0399

	Per cent.
Distillate up to 205° C.	15.9
" 205–255° C.	24.3
" 255–295° C.	12.7
" 295–320° C.	6.8
" 320–330° C.	3.2
Residue	36.6
Loss	0.5
Total	100.0

STATE AGRICULTURAL EXPERIMENT STATION, FT. COLLINS, COLO.

Water-Gas Tar.

Specific gravity at 60° C. 1.152

Water content 6%.

	Per cent.
Distillate up to 235° C.	4.9
" 235–245° C.	1.3
" 245–275° C.	4.0
" 275–305° C.	8.5
" 305–350° C.	15.4
Residue	64.9
Loss	1.0
Total	100.0

SOUTH CAROLINA AGRICULTURAL EXPERIMENT STATION, CLEMSON COLLEGE, S. C.

Creosote.

Specific gravity at 60° C. 1.0531

	Per cent.
Water	trace
Distillate up to 205° C.	8.3
" 205–255° C.	39.1
" 255–295° C.	13.7
" 295–320° C.	8.2
" 320–360° C.	16.5
Residue	14.1
Loss	0.1
Total	100.0

Index of refraction values ranges between 1.5785 and 1.6190.

UNIVERSITY OF MINNESOTA AGRICULTURAL EXPERIMENT STATION, ZUMBRA HEIGHTS, MINN.

Creosote.

Specific gravity at 60° C. 1.0655

	Per cent.
Water	0.4
Distillate up to 205° C.	14.5
" 205–255° C.	35.2
" 255–295° C.	9.0
" 295–320° C.	5.3
Residue	35.2
Loss	0.4
Total	100.0

Index of refraction values ranges between 1.5882 in fraction 225° C. to 235° C., to 1.6153 in fraction 295° C. to 305° C.

Water-Gas Tar.

Specific gravity at 60° C. 1.1455.

	Per cent.
Water	2.6
Distillate up to 205° C.	1.6
" 205–255° C.	13.2
" 255–295° C.	6.6
" 295–320° C.	6.2
" 320–350° C.	17.3
Residue	52.3
Loss	0.2
Total	100.0

The index of refractions varies from 1.5934 in fraction 225° C. to 235° C., to 1.6174 in fraction 295° C. to 305° C.

TABLE 2.—CONDITION OF POSTS OF NON-DURABLE SPECIES IN VARIOUS LOCALITIES.

Preservative: Coal-tar creosote. Open-tank Treatment: Butts, hot bath. Entire post, cold bath.

Location.	Years of Service.	Total Number of Posts Included in Tests.	Sound.		Partly Decayed.		Badly Decayed.		Removed on Account of Decay.	
			No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.
Alabama Polytechnic Institute, Auburn, Ala.	9¾	121	61	50.5	25	20.6	8	6.6	27	22.3
Maryland Agricultural Experiment Station, College Park, Md.	11	384	362	94.2	12	3.2	5	1.3	5	1.3
North Louisiana Agricultural Experiment Station, Calhoun, La.	10¼–12¼	823	467	56.8	128	15.6	23	2.8	205	24.8
South Carolina Agricultural Experiment Station, Clemson College, S. C.	11	436	238	54.6	33	7.6	9	2.0	156	35.8
University of Minnesota, Zumbra Heights, Minn.	11½	697	590	84.7	59	8.4	2	0.3	46	6.6
Total		2461	1718	70.0	257	10.4	47	1.9	439	17.8

Species: Basswood, bay, beech (white heart), birch, cottonwood, elm (red), gum (black), gum (sweet), gum (tupelo), maple (red), maple (sugar), oak (chestnut), oak (pin), oak (red), pine (loblolly), pine (shortleaf), pine (scrub), poplar (silver), poplar (yellow), sycamore, willow (black), willow (white).

TABLE 3.—CONDITION OF NON-DURABLE SPECIES IN VARIOUS LOCALITIES.

Preservative: Coal-tar creosote. Open-tank treatment: Butt treatment only.

Location.	Years of Service.	Total Number of Posts Included in Tests.	Sound.		Partly Decayed.		Badly Decayed.		Removed on Account of Decay.		Remarks.
			No.	Per cent.	No.	Per cent.	No.	Per cent.	No	Per cent.	
Iowa State College, Ames, Iowa	11	139	56	40.3	34	24.5	3	2.1	46	33.1	Hot and cold bath.
Maryland Agricultural Experiment Station, College Park, Md.	11	72	30	41.7	19	26.4	19	26.4	4	5.5	"
University of Minnesota, Zumbra Heights, Minn.	11½	127	21	16.5	94	74.0	2	1.6	10	7.9	"
Total*	------	338	107	31.6	147	43.5	24	7.1	60	17.8	"
Routt National Forest, Colorado**	9	42	35	83.4	6	14.3	1	2.3	-------	-------	Hot and cold bath.
		86	62	72.1	13	15.1	11	12.8	-------	-------	Hot bath only.

*Species: Basswood, beech (white heart), birch (yellow), cottonwood, elm (red), elm (white), gum (black), gum (sweet), maple (red), oak (chestnut), oak (pin), oak (red), pine (shortleaf), poplar (silver), poplar (yellow), sycamore, willow (black), willow (white).

**Species: Fir (alpine), pine (lodgepole), spruce (Engleman).

TABLE 4.—CONDITION OF POSTS OF DURABLE SPECIES IN VARIOUS LOCALITIES.

Preservative: Coal-tar creosote. Open-tank treatment: Butts, hot bath. Entire post, cold bath.

Location.	Years of Service.	Total Number of Posts Included in Tests.	Sound.		Partly Decayed.		Badly Decayed.		Removed on Account of Decay.	
			No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.
Maryland Agricultural Experiment Station, College Park, Md.	11	140	186	97.1	4	2.9	------	------	------	------
North Louisiana Agricultural Experiment Station, Calhoun, La.	10¼-12¼	71	64	90.2	2	2.8	------	------	5	7.0
South Carolina Agricultural Experiment Station, Clemson College, S. C.	11	42	18	42.9	3	7.1	------	------	21	50.0
University of Minnesota, Zumbra Heights, Minn.	11½	2	1	50.0	------	------	------	------	1	50.0
Total	------	255	219	86.0	9	3.5	------	------	27	10.5

Species: Cedar (red), cypress, chestnut, locust (black), oak (post), oak (white). (Most of decayed posts were post oak set at Clemson College, S. C.)

TABLE 5.—CONDITION OF POSTS OF DURABLE SPECIES IN VARIOUS LOCALITIES.

Preservative: Coal-tar creosote. Open-tank treatment: Butt treatment only.

Location.	Years of Service.	Total Number of Posts Included in Tests.	Sound.		Decayed. Partly		Badly Decayed.		Removed on Account of Decay.	
			No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.
Iowa State College, Ames, Ia.	11	496	453	91.3	43	8.7	------	------	------	------
Maryland Agricultural Experiment Station, College Park, Md.	11	14	14	100.0	------	------	------	------	------	------
Total	------	510	467	91.5	43	8.5	------	------	------	------

Species: Cedar (red), cedar (white), chestnut, locust (black), oak (white). (Most of these posts were white cedar placed at Ames, Iowa.)

TABLE 6.—CONDITION OF POSTS GIVEN COLD OIL BATH ONLY.

Preservative: Coal-tar creosote. Open-tank treatment: Entire post treated in cold oil bath.

Location.	Years of Service.	Total Number of Posts Included in Tests.	Sound.		Partly Decayed.		Badly Decayed.		Removed on Account of Decay.	
			No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.
University of Minnesota, Zumbra Heights, Minn.	11½	93	61	65.6	2	2.2	-------	-------	30	32.2

Species: Basswood, birch,, cottonwood, elm, maple, and red oak. (These posts are all in a location where service conditions are not severe.)

TABLE 7.—CONDITION OF POSTS OF NON-DURABLE SPECIES TREATED WITH WATER-GAS TAR AND COAL-TAR CREOSOTE.

Open-tank treatment: Butts, hot bath water-gas tar. Entire post, coal-tar creosote.

Location.	Years of Service.	Total Number of Posts Included in Tests.	Sound.		Partly Decayed.		Badly Decayed.		Removed on Account of Decay.	
			No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.
Maryland Agricultural Experiment Station, College Park, Md.	11	47	40	85.2	6	12.7	1	2.1	------	------
University of Minnesota, Zumbra Heights, Minn.	11½	98	88	89.7	4	4.1	1	1.1	5	5.1
Total	------	145	128	88.3	10	6.9	2	1.4	5	3.4

Species: Basswood, beech (white heart), oak (red), poplar (silver), sycamore, willow (black and white).

TABLE 8.—CONDITION OF POSTS OF NON-DURABLE SPECIES TREATED WITH WATER-GAS TAR.
Open-tank treatment: Butts only treated.

Location.	Years of Service.	Total Number of Posts Included in Tests.	Sound.		Partly Decayed.		Badly Decayed.		Removed on Account of Decay.	
			No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.
Maryland Agricultural Experiment Station, College Park, Md.	11	29	6	20.6	9	31.2	8	27.6	6	20.6
University of Minnesota, Zumbra Heights, Minn.	11½	51	8	15.7	30	58.8	-------	-------	13	25.5
Total	--------------	80	14	17.5	39	48.8	8	10.0	19	23.7

Species: Basswood, oak (chestnut), oak (pin), oak (red), pin (scrub).

TABLE 9.—CONDITION OF POSTS GIVEN A BRUSH TREATMENT WITH COAL-TAR CREOSOTE.

Butts, 3 coats. Tops, 2 coats.

Location.	Years of Service.	Total Number of Posts Included in Tests.	Sound.		Partly Decayed.		Badly Decayed.		Removed on Account of Decay.	
			No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.
South Carolina Agricultural Experiment Station, Clemson College, S. C.	11	70	2*	2.8	--------	--------	--------	--------	68	97.2

Species: Gum (black), hickory, oak (post), pine (shortleaf), poplar (yellow).

***One post oak and one shortleaf pine post.**

Table 1. - Condition of experimental posts at last inspections

Open Tank Treatments Entire Post Treated (Butts given hot bath, Entire post cold bath)

Species	Preservative	Location	Date of last inspection	Years of service	Number of posts included in tests	Per cent sound	Per cent partly decayed	Per cent badly decayed	Per cent removed on account of decay	Remarks
Basswood	Coal tar creosote	Sumbra Heights, Miss.	June, 1920	11-1/2	312	77.2	13.8	----	9.0	
"	Water-gas tar and coal tar creosote	"	"	11-1/2	15	6.6	53.4	----	40.0	Hot bath,water gas tar;cold bath,coal tar creosote
Bay, sweet	Coal tar creosote	Calhoun, La.	July, 1920	10-1/4 to 12-1/4	125	45.6	8.0	2.4	44.0	
Beech, white heart	"	College Park, Md.	June, 1919	11	25	100.0	----	----	----	
"	Crude petroleum and coal tar creosote	"	"	11	10	100.0	----	----	----	Hot bath,crude petroleum;cold bath,coal tar creosote
"	Water-gas tar and coal tar creosote	"	"	11	5	80.0	20.0	----	----	Hot bath,water gas tar;cold bath,coal tar creosote
Birch, black	Coal tar creosote	"	"	11	29	100.0	----	----	----	
"	Crude petroleum and coal tar creosote	"	"	11	10	50.0	----	----	50.0	Hot bath,crude petroleum;cold bath,coal tar creosote
Birch, yellow	Coal tar creosote	Sumbra Heights, Miss.	June, 1920	11-1/2	4	75.0	----	----	25.0	
Cedar, eastern red	"	College Park, Md.	June, 1919	11	30	100.0	----	----	----	
"	Crude petroleum and coal tar creosote	"	"	11	5	100.0	----	----	----	Hot bath,crude petroleum;cold bath,coal tar creosote
Chestnut	Coal tar creosote	"	"	11	30	93.0	7.0	----	----	
"	Crude petroleum and coal tar creosote	"	"	11	10	100.0	----	----	----	Hot bath,crude petroleum;cold bath,coal tar creosote
Cottonwood	Coal tar creosote	Sumbra Heights, Miss.	June, 1920	11-1/2	37	86.5	2.7	2.7	8.1	
Cypress	"	Calhoun, La.	July, 1920	10-1/4 to 12-1/4	71	90.1	2.8	----	7.1	
Elm	"	Sumbra Heights, Miss.	June, 1920	11-1/2	9	100.0	----	----	----	
Gum, black	"	Clemson College, S.C.	July, 1920	11	12	41.7	8.3	8.3	41.7	
"	"	College Park, Md.	June, 1919	11	36	94.5	5.5	----	----	
"	"	Calhoun, La.	July, 1920	10-1/4 to 12-1/4	60	81.8	1.6	----	16.6	
Gum, sweet	"	"	"	10-1/4 to 12-1/4	177	69.5	5.1	0.6	24.8	
"	"	Auburn, Ala.	"	9-3/4	36	44.5	27.8	8.3	19.4	
"	"	Clemson College, S.C.	"	----	10	----	----	----	100.0	
"	"	College Park, Md.	June, 1919	11	26	96.2	----	3.8	----	
"	Crude petroleum and coal tar creosote	"	"	11	10	90.0	----	----	10.0	Hot bath,crude petroleum;cold bath,coal tar creosote
Gum, tupelo	Coal tar creosote	Calhoun, La.	July, 1920	10-1/4 to 12-1/4	75	69.4	9.3	----	21.3	
Locust, black	"	College Park, Md.	June, 1919	11	36	97.2	2.8	----	----	
"	Crude petroleum and coal tar creosote	"	"	11	5	100.0	----	----	----	Hot bath,crude petroleum;cold bath,coal tar creosote
Maple, red	Coal tar creosote	"	"	11	25	96.0	----	4.0	----	
"	Crude petroleum and coal tar creosote	"	"	11	5	60.0	----	----	40.0	
Maple, sugar	Coal tar creosote	Sumbra Heights, Miss.	June, 1920	11-1/2	29	93.2	3.4	----	3.4	
Oak, chestnut	"	College Park, Md.	June, 1919	11	15	80.0	13.3	6.7	----	
"	Crude petroleum and coal tar creosote	"	"	11	20	100.0	----	----	----	Hot bath,crude petroleum;cold bath,coal tar creosote
Oak, pin	Coal tar creosote	"	"	11	18	94.5	5.5	----	----	
"	Crude petroleum and coal tar creosote	"	"	11	9	100.0	----	----	----	Hot bath,crude petroleum;cold bath,coal tar creosote
Oak, post	Coal tar creosote	Clemson College, S.C.	July, 1920	11	42	42.9	7.1	----	50.0	
Oak, red	"	"	"	11	9	22.2	----	----	77.8	
"	"	College Park, Md.	June, 1919	11	80	100.0	----	----	----	
"	Water-gas tar and coal tar creosote	"	"	11	14	71.5	21.4	7.1	----	Hot bath,water-gas tar;cold bath,coal tar creosote
"	Coal tar creosote	Sumbra Heights, Miss.	June, 1920	11-1/2	300	91.3	4.3	0.4	4.0	
"	Water-gas tar and coal tar creosote	"	"	11	72	97.3	----	----	2.7	Hot bath,water-gas tar;cold bath,coal tar creosote
Oak, white	Coal tar creosote	College Park, Md.	June, 1919	11	44	97.7	2.3	----	----	
"	"	Sumbra Heights, Miss.	June, 1920	11-1/2	8	50.0	----	----	50.0	

(Continued)

Table 1 (Continued) (2)

Species	Preservative	Location	Date of last inspection	Years of service	Number of posts included in tests	Per cent sound	Per cent partly decayed	Per cent badly decayed	Per cent removed on account of decay	Remarks
Pine, loblolly	Coal tar creosote	Calhoun, La.	July, 1920	10-1/4 to 12-1/4	386	48.2	25.1	6.0	20.7	
"	"	Auburn, Ala.	"	9-3/4	71	49.3	16.9	5.6	28.2	
Pine, longleaf and shortleaf	5% Antimonin	A.T.& S.F. Cleveland Texas	Nov. 1919	6	13	----	----	----	100.0	All posts removed within 6 years
"	15% "	"	"	6	13	----	----	----	100.0	
"	25% "	"	"	6	12	----	----	----	100.0	
"	1% Sodium silico fluoride	"	"	6	13	----	100.0	----	----	
"	2% "	"	"	6	14	----	100.0	----	----	
"	2% Zinc chloride 0.471# Dry salt/cu.ft.	"	"	6	10	100.0	----	----	----	
"	4-1/2% " 1.20 # "	"	"	6	11	100.0	----	----	----	
Pine, shortleaf	Coal tar creosote	Clemson College, S C.	July, 1920	11	291	55.4	7.5	0.7	36.4	
Pine, scrub	"	College Park, Md.	June, 1919	11	54	96.3	3.7	----	----	
"	Crude petroleum and coal tar creosote	"	"	11	10	100.0	----	----	----	Hot bath, crude petroleum; cold bath, coal tar creosote
"	Asphaltum and coal tar creosote	"	"	11	11	100.0	----	----	----	Hot bath, crude asphaltum; cold bath, coal tar creosote
Poplar, silver	Coal tar creosote	"	"	11	19	73.7	10.5	5.3	10.4	
"	Crude petroleum and coal tar creosote	"	"	11	5	20.0	----	----	80.0	Hot bath, crude petroleum; cold bath, coal tar creosote
"	Water-gas tar and coal tar creosote	"	"	11	11	91.0	9.0	----	----	Hot bath, water-gas tar; cold bath, coal tar creosote
Poplar, yellow	Coal tar creosote	Auburn, Ala.	July, 1920	9-3/4	14	71.5	21.4	7.1	----	
"	"	Clemson College, S C.	"	11	22	27.3	13.6	9.1	50.0	
"	"	College Park, Md.	June, 1919	11	41	92.6	7.4	----	----	
Sycamore	"	"	"	11	26	100.0	----	----	----	
"	Crude petroleum and coal tar creosote	"	"	11	5	100.0	----	----	----	Hot bath, crude petroleum; cold bath, coal tar creosote
"	Water-gas tar and coal tar creosote	"	"	11	8	100.0	----	----	----	Hot bath, water-gas tar; cold bath, coal tar creosote
Willow, black and white	Coal tar creosote	"	"	11	50	92.0	----	2.0	6.0	
"	Crude petroleum and coal tar creosote	"	"	11	9	33.3	----	11.1	55.6	Hot bath, crude petroleum; cold bath, coal tar creosote
"	Water-gas tar and coal tar creosote	"	"	11	9	89.0	11.0	----	----	Hot bath, water-gas tar; cold bath, coal tar creosote
"	Asphaltum and coal tar creosote	"	"	11	4	25.0	----	----	75.0	Hot bath, crude asphaltum; cold bath, coal tar creosote
Mixed	Coal tar creosote	University Farm, Minneapolis, Minn.	Oct. 1920	8	8	100.0	----	----	----	Species: ash and jack pine
Entire Post Treated - Cold Oil Bath Only										
Basswood	Coal tar creosote	Zumbra Heights, Minn.	June, 1920	11-1/2	48	54.2	4.1	----	41.7	
Elm, red	"	"	"	11-1/2	5	20.0	----	----	80.0	
Maple, sugar	"	"	"	11-1/2	4	50.0	----	----	50.0	
Oak, red	"	"	"	11-1/2	35	88.6	----	----	11.4	
Entire Post Treated - Pressure Process										
Pine, lodgepole	Coal tar creosote	Bozeman, Mont.	1916	1	610	100.0	----	----	----	Low pressure
Pine, longleaf and shortleaf	"	A.T.& S.F. Cleveland Texas	Nov. 1919	6	17	100.0	----	----	----	Full cell treatment. Ave.abs.34.8# per cu.ft.
"	"	"	"	6	22	100.0	----	----	----	Rueping process. Ave.abs. 8# per cu.ft.
Mixed	75% Gas oil 25% Coal tar creosote	Univ.Farm, Madison, Wis.	Oct. 1920	4	47	100.0	----	----	----	Species: Birch, oak (black), cedar, oak (white), willow;
Butts Dipped										
Mixed	Coal tar creosote	Univ.Farm, Minneapolis, Minn.	Oct. 1920	8	54	55.5	----	31.5	13.0	Species: Ash, Balsam, birch, cedar, pine (Jack), spruce
Mixed	Carbolineum	"	"	8	40	75.0	----	17.5	7.5	Species: Ash, Balsam, Birch, cedar, pine (Jack), poplar, spruce

(Continued)

Table 1 (Continued) (3)

Open Tank Treatments Butts only Treated

Species	Preservative	Location	Date of last inspection	Years of service	Number of posts included in tests	Per cent sound	Per cent partly decayed	Per cent badly decayed	Per cent removed on account of decay	Remarks
Ash	Coal tar creosote	Ames, Iowa	Aug. 1920	11	40	45.0	22.5	----	32.5	
Basswood	"	"	"	11	15	40.0	33.3	13.4	13.3	
"	"	Zumbra Heights, Minn.	June, 1920	11-1/2	15	6.6	53.4	----	40.0	
"	Water-gas tar	"	"	11-1/2	13	----	30.7	----	69.3	
Beech, white heart	Coal tar creosote	College Park, Md.	June, 1919	11	5	40.0	20.0	----	40.0	
Birch, yellow	"	Zumbra Heights, Minn.	June, 1920	--	3	----	----	----	100.0	
"	Water-gas tar	College Park, Md.	June, 1919	11	4	25.0	75.0	----	----	
Butternut	Coal tar creosote	Ames, Iowa	Aug. 1920	11	21	42.8	9.6	----	47.6	
Cedar, red	"	College Park, Md.	June, 1919	11	6	100.0	----	----	----	
Cedar, white	"	Ames, Iowa	Aug. 1920	10 to 11	496	91.5	8.5	----	----	
Chestnut	"	College Park, Md.	June, 1919	11	3	100.0	----	----	----	
Cottonwood	"	Zumbra Heights, Minn.	June, 1920	11-1/2	2	----	50.0	----	50.0	
Elm, white	"	Ames, Iowa	"	11	14	50.0	----	7.2	42.8	
Fir, Alpine	Water-gas tar	Ft. Collins, Colo.	1918	6	9	66.0	34.0	----	----	Hot bath only
"	Coal tar creosote	Routt National Forest Colo.	1919	9	5	100.0	----	----	----	Hot bath - Cooling over night
"	"	"	"	9	7	71.4	14.3	14.3	----	Hot bath - Short cooling
"	"	"	"	9	26	61.6	11.6	26.8	----	Hot bath - No cooling
Gum, black	"	College Park, Md.	June, 1919	11	5	40.0	----	60.0	----	
Gum, sweet	"	"	"	11	5	----	40.0	40.0	20.0	
Locust, black	"	"	"	11	3	100.0	----	----	----	
Maple, red	"	"	"	11	12	58.3	8.3	33.4	----	
Oak, chestnut	Water-gas tar	"	"	11	5	40.0	20.0	40.0	----	
Oak, pin	Coal tar creosote	"	"	11	7	43.0	14.0	43.0	----	
"	Water-gas tar	"	"	11	7	----	28.5	43.0	28.5	
Oak, red	Coal tar creosote	"	"	11	5	20.0	60.0	20.0	----	
"	"	Zumbra Heights, Minn.	June, 1920	11-1/2	106	17.2	80.9	1.9	----	
"	"	Ames, Iowa	Aug. 1920	11	5	20.0	20.0		60.0	
"	Water-gas tar	Zumbra Heights, Minn.	June 1920	11-1/2	38	21.0	68.5	----	10.5	
Oak, white	Coal tar creosote	College Park, Md.	"	11	2	100.0	----	----		
Pine, lodgepole	Water-gas tar	Ft. Collins, Colo.	1918	6	19	63.0	31.0	6.0	----	Hot bath only
"	"	"	"	6	20	95.0	----	5.0	----	(19-3/4 hours in cold bath)
"	"	"	"	6	20	95.0	----	----	5.0	(1 to 6 hours in cold bath)
"	Coal tar creosote	Routt Nat'l Forest Colo.	1919	9	3	66.7	33.3	----	----	Hot bath, cooling over night
"	"	"	"	9	3	33.3	66.7	----	----	Hot bath, short cooling
"	"	"	"	9	26	69.3	30.7	----	----	Hot bath, no cooling
Pine, scrub	Water-gas tar	College Park, Md.	June, 1919	11	12	25.0	25.0	25.0	25.0	
"	Asphaltum	"	"	11	5	20.0	20.0	20.0	40.0	Hot asphaltum
Poplar, silver	Coal tar creosote	"	"	11	10	40.0	30.0	30.0	----	
Poplar, yellow	"	"	"	11	6	40.0	60.0	----	----	
Spruce, Engleman	Water-gas tar	Ft. Collins, Colo.	1918	6	19	58.0	26.0	16.0	----	Hot bath only
"	"	"	"	6	20	95.0	5.0	----	----	(19-3/4 hours in cold bath)
"	"	"	"	6	20	75.0	20.0	----	5.0	(1 to 6 hours in cold bath)
"	Coal tar creosote	Routt Nat'l Forest, Colo.	1919	9	3	100.0	----	----	----	Hot bath, cooling over night
"	"	"	"	9	21	90.5	9.5	----	----	Hot bath, short cooling
"	"	"	"	9	34	82.5	5.9	11.6	----	Hot bath, no cooling
Sycamore	"	College Park, Md.	June, 1919	11	5	----	40.0	40.0	20.0	
Walnut, black	"	Ames, Iowa	Aug. 1920	11	26	58.0	38.0	----	4.0	
Willow, black & white	"	College Park, Md.	June, 1919	11	14	64.3	28.6	7.1	----	
"	Asphaltum	"	"	11	4	25.0	----	25.0	50.0	
"	Coal tar creosote	Ames, Iowa	Aug. 1920	11	44	34.1	38.6		27.3	
Mixed	"	University Farm, Minneapolis, Minn.	Oct. 1920	8	86	81.4	----	15.1	3.5	Species: Ash, Balsam, Birch, Cedar, Pine (Jack), Poplar

Brush Treatments - entire Post Treated

Species	Preservative	Location	Date of last inspection	Years of service	Number of posts included in tests	Per cent sound	Per cent partly decayed	Per cent badly decayed	Per cent removed on account of decay	Remarks
Fir, Alpine	Water-gas tar	Ft. Collins, Colo.	1918	6	10	90.0	10.0	----	----	2 coats
Gum, black	Coal tar creosote	Clemson College, S.C.	July, 1920	--	5	----	----	----	100.0	Ave. life 7.2 years. Butts 3 coats, tops 2 coats
Hickory	"	"	"	--	3	----	----	----	100.0	Ave. life 8.3 years. Butts 3 coats, tops 2 coats.
Oak, post	"	"	"	11	7	14.6	----	----	85.6	Butts 3 coats, tops 2 coats.
Pine, lodgepole	Water-gas tar	Ft. Collins, Colo.	1918	6	20	45.0	50.0	5.0	----	2 coats
"	Crude oil	"	"	6	20	5.0	45.0	10.0	40.0	2 coats
Pine, longleaf and shortleaf	Coal tar creosote	A.T.& S.F. Cleveland Texas	Nov. 1919	6	27	----	----	----	100.0	All posts removed within 6 years.
"	Carbolineum	"	"	6	15	----	----	----	100.0	"
"	Locustine	"	"	6	15	----	----	----	100.0	"
"	Lyster wood preserver	"	"	6	15	----	----	----	100.0	"
"	R.I.W. #1129	"	"	6	5	----	----	----	100.0	"
"	Reeves wood preserver	"	"	6	5	80.0	----	20.0	----	

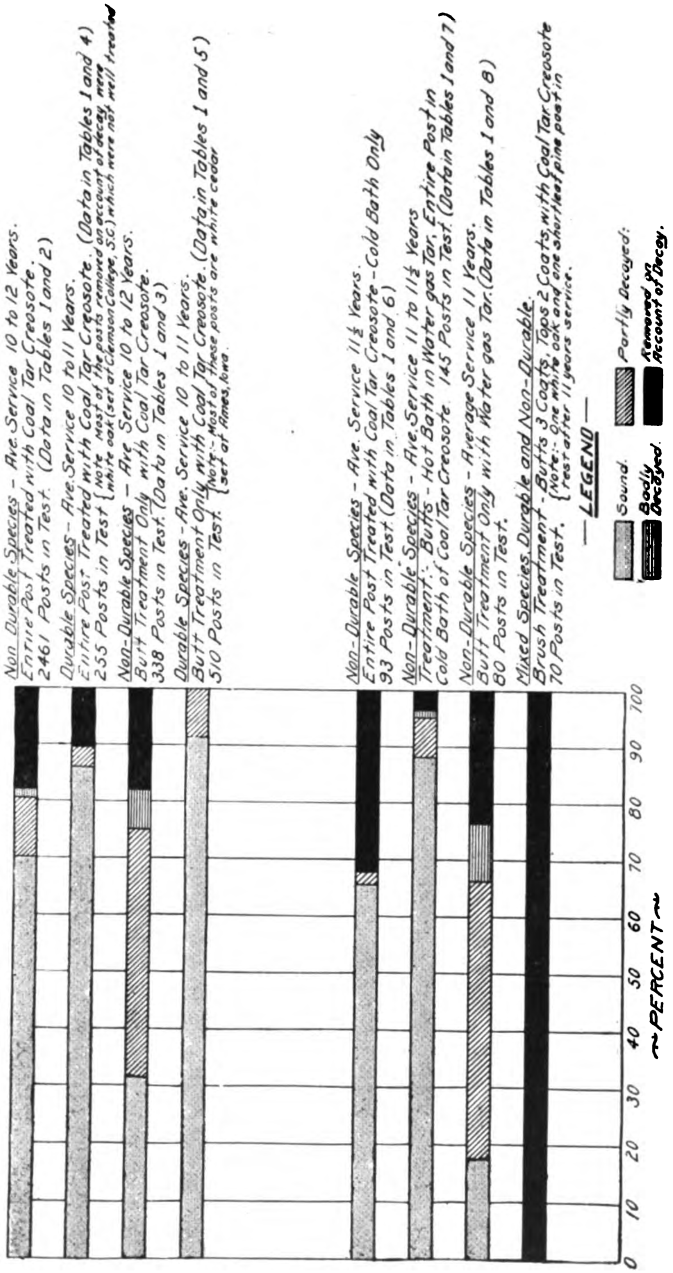
(Continued)

Table 1 (Continued) (4)

Species	Preservative	Location	Date of last inspection	Years of service	Number of parts included in tests	Per cent sound	Per cent partly decayed	Per cent badly decayed	Per cent removed on account of decay	Remarks
Pine, shortleaf	Coal tar creosote	Clemson College, S.C.	July, 1920	11	56	1.8	----	----	98.2	Butts 3 coats, tops 2 coats
Spruce, Engelmann	Water-gas tar	Ft.Collins, Colo.	1918	6	20	40.0	35.0	20.0	5.0	2 coats
"	Crude oil	"	"	6	20	----	15.0	40.0	45.0	"
Mixed	Coal tar creosote	University Farm, Minneapolis, Minn.	Oct. 1920	8	14	28.6	----	50.0	21.4	Species: Ash, Cedar, Pine (Jack), Spruce
"	Carbolineum	"	"	8	19	36.8	----	26.8	36.4	"
Butts Charred										
Gum, black	----	Clemson College, S.C.	July, 1920	---	2	----	----	----	100.0	Ave.life 3 years
Hickory	----	"	"	---	2	----	----	----	100.0	Ave.life 4-1/2 years
Larch	----	Colville Nat'l Forest, Washington	May, 1920	8	179	44.1	28.5	25.1	2.3	
Pine, shortleaf	----	Clemson College, S.C.	July, 1920	---	3	----	----	----	100.0	Ave.life 8 years
Untreated										
Aspen	----	Flagstaff, Ariz. (Exp.station)	July, 1920	10	20	----	20.0	30.0	50.0	
Cedar, white	----	Ames, Iowa	Aug. 1920	10-1/2	11	91.0	----	----	9.0	
"	----	"	"	8-1/2	8	50.0	37.5	----	12.5	
Chestnut	----	College Park, Md.	June, 1919	11	4	75.0	25.0	----	----	
"	----	Waterbury, Conn.	Nov. 1919	6	382	84.4	15.6	----	----	Peeled
"	----	St. [illegible], Pa.	"	6	10	90.0	10.0	----	----	"
"	----	"	"	6	36	11.0	89.0	----	----	Unpeeled
Fir, Alpine	----	Ft.Collins, Colo.	1918	6	10	----	80.0	20.0	----	
"	----	Routt Nat'l Forest, Colorado	1919	9	4	50.0	50.0	----	----	
Fir, Douglas	----	Flagstaff, Ariz. (Exp.station)	July, 1920	10	12	41.7	25.0	33.3	----	
Gum, black	----	Clemson College, S.C.	"	----	2	----	----	----	100.0	Ave.life 6 years
Hickory	----	"	"	---	2	----	----	----	100.0	"
Juniper	----	Flagstaff, Ariz. (Exp.station)	"	10	20	30.0	65.0	5.0	----	
Locust, black	----	College Park, Md.	June, 1919	11	25	72.0	28.0	----	----	
Oak, chestnut	----	"	"	11	4	----	----	25.0	75.0	
Oak, gambel	----	Flagstaff, Ariz. (Exp.station)	July, 1920	10	10	----	30.0	70.0	----	
Oak, pin	----	College Park, Md.	June, 1919	11	5	20.0	----	----	80.0	
Oak, post	----	Clemson College, S.C.	July, 1920	---	2	----	----	----	100.0	Ave.life 7-1/2 years
Oak, red	----	"	"	---	1	----	----	----	100.0	Ave.life 5 years
"	----	College Park, Md.	June, 1919	11	3	----	33.3	----	66.7	
Oak, white	----	"	"	---	2	----	----	----	100.0	Ave.life 10 years
"	----	Oregon, Wis.	Oct. 1920	7-1/2	566	26.5	44.3	12.2	18.0	
Pine, limber	----	Flagstaff, Ariz. (Exp.station)	July, 1920	10	15	60.0	20.0	----	----	
Pine, lodgepole	----	Ft.Collins, Colo.	1918	6	20	----	50.0	5.0	45.0	
Pine, longleaf and shortleaf	----	A.T.& S.F. Cleveland Texas	Nov. 1919	6	15	----	----	----	100.0	All removed within 6 years
Pine, pinon	----	Flagstaff, Ariz. (Exp.station)	July, 1920	10	10	----	20.0	80.0	----	
Pine, shortleaf	----	Clemson College, S.C.	"	---	7	----	----	----	100.0	Ave.life 3.9 years
Pine, yellow	----	Flagstaff, Ariz. (Exp.station)	"	10	31	22.3	6.5	39.0	32.2	
Poplar, yellow	----	Clemson College, S.C.	"	----	3	----	----	----	100.0	Ave.life 8 years
Spruce, Engelmann	----	Ft.Collins, Colo.	1918	6	20	----	15.0	40.0	45.0	
"	----	Routt Nat'l Forest, Colorado	1919	9	10	50.0	----	30.0	20.0	

Table 1a. - Experimental posts which have not been recently inspected

Species	Preservative	Location	Date of last inspection	Years of service	Number of posts included in tests	Per cent sound	Per cent partly decayed	Per cent badly decayed	Per cent removed on account of decay	Remarks
Hot and Cold Bath - Butt Treatment Only										
Cedar, red	Coal tar creosote	Nat'l Bison Range, Montana	Sept. 1916	7	25 miles 456 posts to mile	100.0	----	----	----	
Hot and Cold Bath Butt Treatment - Tops Brush Treated										
Eucalyptus	Coal tar creosote	Santa Barbara Nat'l Forest, Cal.	1915	8	6	33.3	66.6	----	----	Posts green and unpeeled
"	"	"	"	8	3	66.7	----	33.3	----	Posts seasoned and unpeeled
Hot Bath Only - Butt Treatment										
Eucalyptus	Coal tar creosote	Santa Barbara Nat'l Forest, Cal.	1913	8	61	43.2	12.4	44.4	----	Posts green and unpeeled
"	"	"	"	8	38	60.5	15.8	23.7	----	Posts, green peeled
"	"	"	"	8	16	87.6	6.2	6.2	----	Posts seasoned and unpeeled
Untreated										
Cedar	----	California Nat'l Forest	1915	5	63	100.0	----	----	----	
"	----	Plumas Nat'l Forest, California	1916	3	12	91.7	8.3	----	----	
"	----	Sierra Nat'l Forest, California	Dec. 1916	4	61	95.2	4.8	----	----	
"	----	Trinity Nat'l Forest, California	Apr. 1917	6	76	84.2	15.8	----	----	
Juniper	----	Mono Nat'l Forest, Cal	May. 1917	7	100	100.0	----	----	----	


Non Durable Species - Ave. Service 10 to 12 Years.
Entire Post Treated with Coal Tar Creosote.
2461 Posts in Test. (Data in Tables 1 and 2)
Durable Species - Ave. Service 10 to 11 Years.
Entire Post Treated with Coal Tar Creosote. (Data in Tables 1 and 4)
255 Posts in Test {Note Most of the posts removed on account of decay were white oak (set at Clemson College, S.C.) which were not well treated
Non-Durable Species - Ave Service 10 to 12 Years.
Butt Treatment Only with Coal Tar Creosote.
338 Posts in Test. (Data in Tables 1 and 3)
Durable Species - Ave. Service 10 to 11 Years.
Butt Treatment Only with Coal Tar Creosote. (Data in Tables 1 and 5)
510 Posts in Test. {Note:- Most of these posts are white cedar set at Ames, Iowa
Non-Durable Species - Ave. Service 11½ Years.
Entire Post Treated with Coal Tar Creosote - Cold Bath Only
93 Posts in Test. (Data in Tables 1 and 6)
Non-Durable Species - Ave. Service 11 to 11½ Years
Treatment: Butts - Hot Bath in Water gas Tar, Entire Post in Cold Bath of Coal Tar Creosote. 145 Posts in Test. (Data in Tables 1 and 7)
Non-Durable Species - Average Service 11 Years.
Butt Treatment Only with Water gas Tar. (Data in Tables 1 and 8)
80 Posts in Test.
Mixed Species, Durable and Non-Durable.
Brush Treatment - Butts 3 Coats, Tops 2 Coats, with Coal Tar Creosote
70 Posts in Test. {Note:- One white oak and one shortleaf pine post in test after 11 years service.
— LEGEND —
Sound.
Partly Decayed:
Badly Decayed.
Removed on Account of Decay.
0
10
20
30
40
50
60
70
80
90
100
~PERCENT~

THE PRESIDENT: Gentlemen, if there are any questions Mr. Hunt will be very glad to answer them. If not, we will proceed to the next paper which is "Perforated Butt-Treated Poles," by Mr. W. M. Leavitt.

MR. W. M. LEAVITT: Mr. President and Gentlemen, I notice it is "perforated" cedar poles; we call them "punctured" cedar poles. We only puncture the sapwood and do not perforate the pole. I do not know how much you people know about the cedar pole industry. It is not a very big industry, but we cover quite a little bit of territory. In order that one understands why we have built this machine, and why we are perforating our poles, I want to give them a little history of the cedar pole business.

PERFORATED BUTT-TREATED POLES

By W. M. Leavitt

Western red cedar is recognized by all competent authorities as one of the most durable woods grown in the United States. Poles made from this timber have established for themselves a most enviable reputation. They are straight, light in weight, have a uniform taper, are free from large knots, cut faces and other unsightly features.

Evidence of the recognition western red cedar poles have received is shown by the fact that during the year 1919 these poles were shipped into every State in the United States, excepting Florida, Maryland and Delaware, and into every Province in Canada bordering the United States, excepting Nova Scotia and New Brunswick. This extensive distribution has necessarily brought us into competition with every kind of wood, steel, and cement poles. The business men engaged in this industry have recognized more and more each year that the best way to meet this competition is to give more value for a dollar than their competitors can deliver. The recognition of this fact has resulted in a more careful selection of the cedar timber to be used, better methods and better supervision of the manufacture of the product, and a more careful inspection of the poles before loading on cars, and last, but not least, a careful study of the possibilities of increasing the life of the pole by butt-treating.

Everyone here is probably more or less familiar with the development of the open-tank method, but I am going to take the liberty of reviewing the progress made during the past 15 years in the treatment of western red cedar poles.

I believe that the first commercial plant for open-tank treatment of poles was constructed at the Minnesota Transfer, about 15 years ago. Since that time a large number of plants have been constructed, and I believe I am safe in estimating that at least 50% of the poles, 30 ft. and longer, are butt-treated today before being set. Some of the first plants constructed were very crude affairs. About 8 years ago I constructed a plant at Libby, Montana. This consisted of a steel tank, 5 ft. in diameter, set in the ground, with an improvised fire-place under it. This plant cost about $350.00 complete, and was used to treat several thousand poles, giving them a 15 minute bath in oil heated from 112° to 130° F.

The short-time treatments, regardless of the equipment used, resulted in practically no penetration on most of the poles, and in no case was the penetration sufficiently deep to be any insurance against abrasions or checks occurring after treatment.

About 5 years ago what is now known under the Western Red Cedar Association's specifications, as "B" treatment, was put on the market. This treatment consists of immersing the poles for from 4 hours to 12 hours in oil heated to from 112° to 130° F., followed by cold oil for from 2 hours to 6 hours. A large percentage of the seasoned poles treated by this method showed a very satisfactory penetration, but it was found by experience that no matter how well seasoned the poles were a certain number of them could not be given a satisfactory treatment.

During the last 18 months, due to an increased volume of business and difficult producing conditions, there have been practically no poles available for treatment that have been cut over 12 months. We found that even an hour's immersion in the hot oil would not discolor a large percentage of these comparatively green poles, and that after 6 hours in hot and 4 hours in cold oil only a small percentage of this class of poles showed a penetration exceeding ⅛ inch.

About 3 years ago one of our members conceived the idea of securing a penetration by puncturing the sapwood of the poles with short steel points. He used a rubber belt 8 inches wide and 3 ft. long, and arranged the points so that a perfect penetration would be obtained if the oil traveled lengthwise of the poles 2½ inches, and crosswise ⅛ inch. This was a distinct improvement, and since that time a number of the treating plants have been puncturing all poles that they have treated by the "B" method. Difficulty was experienced, however, in getting a sufficiently deep puncture as the points had to be driven in with wooden hammers, and as this work was done by hand there was no assurance that the work was being properly performed.

About 2 years ago we shipped into the Sandpoint treating plant, for experimental purposes, 1 carload of green poles, 1 carload of poles that had been seasoned 12 months, and 1 carload of poles that had been seasoned over 2 years. A number of the members of our Association who were interested in treating spent nearly a week at Sandpoint on these experiments.

The results of these experiments may be summarized as follows:

> (1) If the sapwood was properly punctured a full sap penetration could be obtained in either a green or a seasoned pole.
>
> (2) It was impossible by the use of steel points in a belt to puncture the sapwood of a pole in a proper and uniform manner.
>
> (3) Where poles were not punctured there was no uniformity of results on either seasoned, partly seasoned, or green poles. A considerable difference in the depth of penetration obtained was often found on the same pole. Very few of the green poles, or poles cut 12 months, or less, showed a penetration of over ⅛ inch.

It was evident that if we were to get a satisfactory penetration, a machine must be built that would secure for us the following results:

> (1) Any depth of puncture desired.
>
> (2) Any desired spacing of the puncture points. These were particularly important in order that the wood fiber be lacerated as little as possible, and at the same time secure a complete impregnation.
>
> (3) Mechanically operated so as to be as free as possible from human error and inefficiency.

We got our machine in operation about May 1, 1920, and since that time practically all poles treated at the Sandpoint plant by the "B" method have been punctured with this machine. We found, however, that a number of improvements must be made, and immediately started building another machine which we got into operation about November 1.

The puncturing is done by 42 iron bars, 4½ ft. long, 3 inches wide, and ¾ inch thick, weighing approximately 37 lbs. each. Each bar is equipped at the bottom end with a detachable point holder so that the depth and the spacing of the puncture can be regulated.

Each bar works independently of all the other bars, in order to take care of the irregularities of the pole. These bars are raised by cams and drop by gravity. The machine is constructed so that the operator can regulate the distance the bars drop by simply raising or lowering the hoist on which the pole rests. The pole is transported under the bars by live rolls and then raised into position by hoists. On the first machine the part of the pole that was to be punctured was supported by 2 wheels, 24 inches in diameter, and 4 inches wide. We found that the weight of the bars, approximately 1,500 lbs., dropping on so small a bearing surface had a tendency to break down the sapwood. In building our new machine we overcome this difficulty by replacing these wheels by 2 oscillating wheels, 24 inches in diameter, and 18 inches wide. These wheels are constructed so that no matter what position the pole is in, or what taper it may have, it will have a full 18-inch bearing surface.

At the present time we are using chisel-shaped points ½ inch long, spaced so that if the oil travels 1½ inches lengthwise of the pole and ⅛ inch crosswise, a complete penetration will be obtained. We used on our first machine the same spacing that was used on the belt.

Careful observation during the past 8 months would indicate that the spacing should be regulated by the amount of free oil it is desired to inject into the average pole, assuming, as I think we can, that weather conditions and the question of whether poles are seasoned, partly seasoned, or green, will be taken care of by the duration of treatment.

It is impossible by this method to put a given amount of oil into a certain area of sapwood. One pole may have only a slight impregnation, which may not be visible for several weeks, while another pole in the same treatment, or the opposite side of the same pole, may be saturated at the end of the treatment. It is not unusual to find in the unpunctured area a complete sap penetration on one side of the pole and less than ¼ inch on the opposite side.

During the month of December we shipped into the plant for experimental purposes a carload of green poles. Most of these poles were given a 10-hour treatment, 6 hours hot and 4 hours cold.

We tested all of these poles with an increment borer, and then sawed and split up the treated area of eight of them. Not one of the poles that was tested showed any penetration whatever in the unpunctured area. The poles that were split showed that the oil had not traveled to exceed ½ inch from the puncture at the time they were taken from the treating tank. The poles that were split were shipped into Spokane, and placed in my basement for observation. We found that there was no uniformity in the travel of the oil from the puncture holes. In sections of some poles the oil traveled as much as 12 inches lengthwise of the pole in 24 hours, and in 1 case, over 2 ft. in 2 weeks, while in another section of the same pole it did not average 2 inches a week. We were unable to observe any difference in the rate of travel, whether the oil was moving toward the top or toward the bottom of the pole.

The time at which a complete impregnation may be observed varies from the time the pole is removed from the treating tank up to 2 months after the time of treatment. In a properly punctured pole, we have not, however, had a single instance where we did not eventually secure a complete impregnation to the depth of the puncture, providing the puncture did not enter the heartwood.

It remains for us to decide what depth of penetration is necessary or desirable, and the amount of free oil we should put into the average pole. When we decide these questions I believe we shall be able to determine the length of point and what spacing is best to use.

We have every reason to believe that the building of this machine represents a long step forward in the preservation of cedar poles, and in order that you may have a better understanding of its operation, we are pleased to show you some moving pictures of our plant at Sandpoint, which were taken the first of this month.

(Mr. Leavitt then showed a number of lantern slides.)

MR. W. M. LEAVITT: If I can give you any additional information I will be glad to do so.

MR. C. M. SPORLEY: May I ask Mr. Leavitt a question? Referring to the temperatures in the first part of his paper he mentioned 112° to 130°.

MR. W. M. LEAVITT: I just made an error of a hundred degrees.

THE PRESIDENT: We will have the next item on the program, "Wood Preservation as a Conservation Policy," by Walter Buehler, illustrated by motion pictures.

WOOD PRESERVATION AS A CONSERVATION POLICY.

By Walter Buehler

High-priced lumber, poor in quality and hard to get, is the goal toward which we are surely driving. In recent years danger signals have appeared along the road, only to be in a large measure ignored.

That we are rapidly using up all standing timber is a truth that can no longer be decried nor ignored. This need not be alarming if proper steps are taken, not only to protect our present stands of timber from fire, not only by embarking on a comprehensive plan of reforestation, but also by conserving what we have. In fact, it is only by the proper coordination of all 3 of these factors that real beneficial results will follow.

To the wood-preserving industry conservation appeals more directly than do the other factors, as it is in this phase of the question that wood preservation plays a most important part. Strange as it may seem, this relationship is not generally recognized by the public at large.

There has recently been published two reports, both by the Forest Service of the United States Department of Agriculture. One is entitled "Timber Depletion, Lumber Prices, Lumber Exports and Concentration of Timber Ownership," and is a report on Senate Resolution No. 311. The other is entitled "Timber Depletion and the Answer." Both of these reports go into the timber problem and its answer in great detail, but neither contains one single word about wood preservation, notwithstanding the fact that authorities have from time to time pointed out that application of efficient protective measures to structural timber will substantially decrease the drain on our forests, and it is a known fact that before the war French forests were still furnishing about 3,000,000 ties annually. Weiss, in his book on wood preservation, estimates that an annual output of 140,000,000 cubic feet of preserved wood is equivalent to the amount of wood produced annually by about 12,000,000 acres of average American forests alone, and if waste is taken into consideration represents a protection given to the annual output of over 25,000,000 acres.

Ovid M. Butler, in a recent article dealing with forest conservation, stated:

"Since we are considering the general subject of making timber last longer, it is perhaps proper to mention first the possibilities of timber preservation. Of ties alone the railroad and electric lines of this country use approximately 120,000,000 a year, of which about 28% are treated. The average life of a railroad tie, properly treated, is 15 years; of an untreated tie, about 7½ years. If all ties were treated, the average consumption would thus be reduced one-half or to 42,500,000 ties, a saving of over 1,500,000 board feet."

In its report of 1920 the tie committee of the American Railway Engineering Association estimates the saving would be somewhat greater, or about 2,000,000,000 board feet.

> **"Railroad ties, however, are not the only wood products subject to profitable preservation treatment. If we include in addition poles, posts, piles, mine props, shingles and lumber used under conditions much subject to decay, the annual saving by the application of efficient preservative practice would amount to some six billion board feet. It is too much to expect of human nature that every stick of timber which technically ought to be treated will be treated, but it is within the realm of reason to save some four billion or five billion feet of timber by extending standard treating practice."**

The rate at which our forests are being used up might well be given serious consideration. W. B. Greeley, forester, in his summary of the report on timber depletion and related subjects, prepared in response to Senate Resolution No. 311, makes this statement:

> "The cutting and loss of merchantable timber consumes about fifty-six billion feet yearly. About forty billion feet of this amount is cut from the virgin forests still left, the rest from second growth. We are even cutting into pulp wood, acid wood and fuel, fourteen billion cubic feet per year of material too small for sawing. All told, we are taking about twenty-six billion cubic feet of material out of our forests every year and growing about six billion feet in them. We are cutting more of every class of timber than we are growing. We are even using up the trees too small for the saw-mill, but upon which our future timber supply depends, three and one-half times as fast as they are being produced. Our annual wood bill includes forty billion feet of lumber, eighty-seven million hewed railroad ties, nearly five and one-half million cords of pulp wood, one-third of which is imported, and one hundred and ten million cords of fuel.
>
> "This use of wood cannot be appreciably reduced without serious injury to agriculture, home building and the manufacturers of the United States. The pressure of war brought our per capita consumption of timber down to three hundred board feet yearly and the country has suffered from it in the shortage of dwellings and the curtailed output of many industries. Even with the large allowance for substitution of other materials, the United States will require at least thirty-five billion feet of lumber yearly, aside from numerous quantities of wood pulp and other products of the forest. We cannot cut our per capita use of lumber to one-half or one-third the present amount, to the level of European countries where lumber is an imported luxury, if our resources are to be developed and our industrial supremacy retained, and we must ourselves grow the great bulk of the wood we need, for large increases in lumber imports are not possible at reasonable prices."

From the same report referred to above we find that timber in the form of lumber, ties, mine timber, fencing, poles, piling and shingles removed each year from the forests of the United States amounts to approximately 3,000,000,000 cubic feet of hardwoods, and 9,000,000,000 cubic feet of softwoods, a total of 12,000,000,000 cubic feet. Assuming that only one-half of this amount is adaptable to treatment, then in the year 1914, which represents the largest output of the wood-preserving industry, we treated only 159,000,000 cubic feet, or approximately 2½% of the assumed treatable material. In 1919 this was even less, the percentage being only about 2%.

What is the answer? The question might well be asked. Why are these facts not better known to the American public? Does the wood-preserving industry lack the punch necessary to drive home the fact that as an industry it is part and parcel of any program to conserve our future timber supply? I was much amused by a newspaper clipping reporting a recent meeting of the Society of American Foresters in New York City, and undoubtedly incorrectly reporting it. It ran as follows:

> "Foresters tell plans to avert wood famine. All wood-using trade associations and forestry organizations have joined in a campaign to save the nation's forests and obtain legislation to avert the famine threatened in paper and lumber industries. The Society of American

> **Foresters, foremost in forestry organization and investigation, and composed entirely of practical foresters, state and federal, held its annual meeting at the Yale Club in West Forty-fourth Street yesterday. The main topic of discussion was how waste products of lumber could be handled to the greatest advantage and what substitutes could be used for lumber. Using more steel for construction purposes than is used at present was one proposal for lumber saving which had general support."**

In other words, the way to save our timber is not to use it. We must admit, and any reasonable man will agree with the general proposition, that substitution of cement, clay, and steel for wood in some classes of structure is desirable. But, to advocate general substitution of these materials as the remedy for the present forestry situation is absurd. Those of you who know anything about the propaganda that has been and is being spread by the lumber substitute manufacturers will readily realize the danger to the lumber industry and, incidentally, to the wood-preserving industry potential in educating the public to the use of substitutes as a conservation measure.

Right along this same line I had occasion a few months ago to discuss depreciation charges on pole lines with the chief engineer of the Public Utilities Commission of one of the Central States. He made this very interesting statement,—he said that he appreciated the fact that treated poles outlasted the untreated and, therefore, merited consideration when depreciation values were being determined, but this fact was being ignored for the reason that concrete poles were rapidly substituting wood poles.

I feel that the wood-preserving industry must awaken to the fact that it is no longer possible, or desirable, to talk and think of preserving wood in terms of ties, paving blocks, piling, poles and structural timbers. We must get down to the commonplace uses in small quantities by every user of wood, whether he buys by the piece or by the carload when such wood is to be used in an environment favorable to decay. Unfortunately, the present location of our available saw-mill timber makes such distribution difficult. Mr. Greeley has stated that not only is the quantity of timber left in the United States being used up much more rapidly than wood is being grown, but the availability of the remaining timber to the average consumer is steadily decreasing.

Wood preservation can only be of maximum service to the consumer when all treatable wood is being treated, and we must recognize that in order to approximate this Utopian ideal, all preservatives of merit and all methods of application have their proper field. It is not necessary for me to point out to this gathering that the non-pressure processes, surface-treatments and the open-tank processes, are in no wise a substitute for pressure processes, but I do wish to make the point that to be of maximum service to the industry we must recognize that all of the processes are necessary for its rapid and ultimate development.

We have on the program of this convention papers on fence posts, silos, poles, wood conduits, mine timbers, in addition to the usual discussion on ties, piling and paving blocks, a much more diversified program than this Association has ever had before. And we must not be content to stop here. This Association has a duty to perform and that is to so standardize all processes and preservatives and so clearly set forth the field of each that its PROCEEDINGS and MANUAL, if one is ever published, will be a source of information, not only for the large consumer but the small one as well.

The increasing use of wood preservation by the large consumers will no doubt serve to popularize it with the small consumer, but unless the small consumer can find a source of reliable information much of the wood he treats will be a disappointment to him, to say nothing of the money loss and the creation of a knocker instead of a booster.

This Association can and should be the fountain head from which all information on wood preservation should spring.

THE PRESIDENT: Are there any questions that anyone would like to ask Mr. Buehler?

MR. J. H. WATERMAN: You have noticed I have been very quiet in this Convention so far, but I want to talk just a minute or two if the Chair will bear with me on the subject that is before us.

I admire Mr. Barth and my friend Buehler here, but I do not go with them—I am not going all the way with them. Men, this is a great age and men want something quick. The world moves fast, and as the Scotchman said: "You can nae get something for naethin'." Now, these beautiful pictures we have had on the screen of what can be done with a dipping process is mighty near getting something for nothing. I was delighted last night when Mr. Horrocks got up and defended the creosote treatment, or the pressure treatment. I was delighted with the way he went after the concrete man, and if the concrete man is here I am with Mr. Horrocks. The concrete man said something like this, that a man with big nails in his shoes or an axe on a raft could walk over the piling and could perforate or punch through the treated part of the piling, and, therefore, the borers could have plenty of opportunity to work. Mr. Horrocks defended it, and he defied, or challenged, this bunch of men with the number of piling they treated in the past few years.

Just a few days before I left a man came to our plant, and he says, "We want to find out what is the matter." He said, "We are treating (and I will not tell you where it was; you can guess it is in the far East, because men do not come from the West to the East to learn, they keep going West) and we are having difficulty with our treated material. We find some of our ties which are treated only give 2 years' life." Now what is the matter? Improper treatment, and I want to emphasize to this convention first, last and all the time, that this hurry-up business I am opposed to. It is all right to say we want good treatment. That is not all; we want better treatment. You men that are engineers—I am not—you always want what is called a factor of safety. Someone said some years ago—I think the Forest Laboratory—that ¼ lb. of zinc chloride per cubic foot would prevent fungus growth in timber. That is true, I presume. I am not going to deny it, but where is your factor of safety? We have learned from experience that it is not safe to put in ¼ lb. of zinc chloride per cubic foot and expect your tie will give service.

Now, I have no objection to the open-tank treatment. I have no objection to the brush-treatment. I have no objection to the spray-treatment, but, men, is it treatment? Remember what you are getting. Some of you men are going home and these PROCEEDINGS are going out through the length and breadth of this great United States, and your operating officers are going to say to you: "You take 4, 5, 6, 7, 8, 9 hours to treat a single charge, where all you have got to do is to take a tank and put in a dozen ties with a crane and lift them out, and away she goes." I am opposed to it—I am opposed to it first, last and all the time. I want the best. Why do we, when we go and buy a hat, if we want a real good one, say we want a Stetson hat? Because, it has a reputation, and if you buy a Stetson hat you get a hat. Why is it that when you want a real good saw you go and get a Disston saw? I am not advertising either one of these men, but when I was a little boy we bought that saw and that saw is on the market today. Men, the pressure treatment will be on the market when the dipping-treatment will be in the grave.

Now, I may stand alone. You can laugh at me if you want to, but I want to emphasize it. Is this convention going to endorse emphatically without anyone except Waterman saying a word against this open-tank treatment? I am opposed to it. I think I have made it clear to you that I am opposed to it. [*Prolonged applause.*]

MR. A. A. BROWN: I looked at those pictures with a great deal of interest. After very carefully treating some of those timbers I noticed that one of the very things that I complained of last night occurred in the pictures, that timbers were treated in the tank and then they were taken out from the tank with ice hooks and a pike pole, immediately perforating the surface and destroying, very largely, the thing that you were paying to have done. This morning in going over the job where we are driving creosoted piles, I chanced to see the foreman pile-driver drive a big spike into a creosoted pile. I took him aside and wanted to know what he meant. He had his instructions not to do that sort of thing. He said he was pulling it down, and said it was difficult to hold a chain on and he needed a spike in it. He pulled the pile down without and I told him he could get his time tonight; we did not want him any longer. [*Applause.*]

I think there is one thing that this convention could do, and one thing that the American Wood-Preservers' Association ought to do, is to emphasize the necessity of care in handling treated materials. It is a very great mistake to put on the screen examples of the misuse of treated timbers and show them to the unsuspecting public when we know better. Men are very much like little boys. I think we are all simply boys grown a little bigger, and we imitate the things we see others do. If we see such things as that done on the screen, and the pictures will probably be shown through the length and breadth of the land, they will have a very detrimental influence.

Next door to us—if some of you gentlemen take that trip on Friday, I would be very glad to show you piling that has been treated by the so-called "feather" method.

I will say here I was very much opposed to the Committee giving any such length of life as 6 years to the feather treatment of piling, for it is a makeshift at best, and I think a very poor proposition. I looked over some of those that are being treated by the so-called feather method, and there is scarcely a square foot of pile not already exposed. They were supposed to paint the pile, then put on burlap and battens and paint the battens, but it seems that the foreman on the job thinks he can get along without putting the burlap on and all the burlap is still stacked up there and the piles being treated without it. Now, the owner of the piling is no doubt feeling rather secure that he is getting a creosoted pile, a pile that is treated. We must view it, I think, from the viewpoint of the layman. He does not discriminate; he does not know enough about it. He sees them put on the creosote paint and all the rest of it, and they tell him that is a creosoted pile. Now, he is being "gyped"; such men are being cheated out of what they suppose they are getting, so I think we should be very careful in the presentation of these makeshift methods of painting and spraying and all the rest of the information if we are going to get any place with the treatment of timber. I believe we are going to get there sooner by doing first-class and high-grade work—work by all means above reproach and approaching perfection as nearly as possible.

If there is any criticism that I have aimed toward the creosoted pile it is with the idea that we are going to get perfection in so far as that is possible. I left a sample of one of many piles that we have cut, and found it to be imperfect, on the table outside. It shows one of the complaints that was made last night where the penetration in small spots is but ⅛ inch to 3/16 inch. Unfortunately, that part of the pile is always on top of the water when in the boon, and is always exposed to damage. We should aim, I believe, at a higher grade of treatment, a more thorough treatment, no makeshifts. Makeshifts should not be condoned.

The other thing that has impressed me in so far as I was able to attend these meetings, is the absence of papers on the cheapening of the process making it more possible for the public to adopt the treatment of timbers, and I believe this Association could with profit set aside all commercial interests, but all joining hands in a very thorough investigation of methods which would tend to cheapen and at the same time be more thorough. I have been impressed by the tremendous amount of brute strength that is apparently used in these plants. It can, I believe, be made a great deal automatic, and consequently, a great deal more thorough, and that would seem to me to be a great fruitful field for future endeavor. [*Applause.*]

MR. WALTER BUEHLER: ———

THE PRESIDENT: Just a minute before I recognize you. I think Mr. Waterman in objecting to many things did not intend to object to the butt-treatment of such pieces of timber as red cedar poles, for which we have never been able to get a better form of treatment. Is that right, Mr. Waterman?

MR. J. H. WATERMAN: Yes, sir.

THE PRESIDENT: Your objection did not cover everything, only certain things?

MR. J. H. WATERMAN: Well, that is all right. Go ahead.

MR. WALTER BUEHLER: Gentlemen, I am not going to defend the use of hooks in creosoted timber, but if the statements of Mr. Waterman and of the gentleman who has just spoken voice the impression that this audience got from my talk, then my mission has absolutely failed.

There is a side to this question which has been lost sight of by the 2 speakers who just commented on my talk. The Committee on Economics in its report yesterday said that there are innumerable cases where pressure-treatment for some reason is either impossible or inadvisable, and the wood must be either treated by non-pressure processes or used without treatment of any kind, or replaced by some structural material. This is especially true in rural communities. Forty-six per cent of all structural wood used in the country is used on the farms.

I hope that I did not give the impression that I am advocating non-pressure treatments for all uses. I thought I made it perfectly clear that we must use intelligence in the selection of the treatment we use on the timber in the environment in which it is going to be placed. Take, for example, the farmer who uses a few fence posts; who has a few buildings where he uses some wood in contact with the ground located in a State where pressure treatment is not available. Take, for example, a mine located in a district surrounded by timber, but where no pressure plant is available, would you advocate that in such environment and under such conditions that this miner or this farmer or this miscellaneous user of timber should put his timber in untreated? The use of the open-tank treatment as I see it is simply a stepping-stone, an educational matter. It is bringing the necessity for preserving our wood to the common user of wood, and as he becomes educated, and as the economics of the situation demand, he will buy pressure-treated timber, but you cannot jump that individual into the use of pressure-treated material from the untreated material he is using at the present time.

There is another question. Those of you who have been using creosote oil in the past few years know that it has not been as available as it should be for the good of the industry,—a condition entirely beyond the control of anyone. This is a little aside from the question, but I want to bring it up right now. We will admit and emphasize the economy in pressure-treated timber, but I want to say that there is a terrific waste of good preservative material going on in this country right now in the pressure plants. Cross-arms up in the air on a pole treated with 12 lbs. of oil to the cubic foot,—is there any justification for it? Is there any justification for giving paving blocks, used in interior construction, a full-cell treatment? Those are just two examples. There are innumerable cases where more preservative is used than should be used.

I believe we have to study this question from the economic side, and when Mr. Waterman says we should use only the best, we should pick the Stetson hat and the Disston saw, we have got to use judgment in what is the best in the environment in which it is going to be used. If I am going out into a logging camp and saw timber I am not going to buy a Stetson hat to wear; I am going to buy the kind of a hat that is going to give me the service in the environment in which I am going to use it. We have to use some intelligence in the selection of our treatments and of our preservatives, and above all in the application of those preservatives, irrespective of the kind of treatment we are going to give the timber. [*Applause.*]

MR. CARL G. CRAWFORD: Mr. President and Gentlemen, I believe that the brush treatment and the open-tank method have a field. That, I think, was pointed out quite clearly in the report of the Committee on the economy of non-pressure treatment, but we as an Association, an Association which is quite technical when commercial associations are considered, must be very careful that we do not give the wrong impression when we talk of the superficial treatments. As I watched the pictures on the screen they seemed to go a good deal farther than the remarks of Mr. Buehler would warrant. We were shown ties treated by the open-tank method. It was pointed out that the pressure treatment is an expensive method, but the brush treatment and the open-tank treatment were quite available.

I saw the statement on the screen that good treatment should be used, therefore, use the open-tank treatment. Now, my point is, will those statements and those pictures give the wrong impression—not to Mr. Waterman, not to Mr. Buehler, but to the public? I have run up against this proposition a great many times, that your creosote oil is no good; your treatment is no good. Why? I ask, why? The answer is, we have tried it out and the timber rotted. I inquired into the situation and found that they had used treatment by the brush or open-tank method and then put it in places for which it was not fitted at all.

Therefore, wood preservation as an industry got a black eye. I heard Mr. Waterman, our former President of this Association, say one time that one treated tie that has rotted will do the industry more harm than 150,000 well treated ties that have lasted for 20 years will do it good. I do not want to be misunderstood, but I do think that we should be very careful in this Association not to give the wrong impression when presenting pictures or discussing methods that will give only a superficial treatment. We should make it clear that such methods should be used only where conditions will warrant them, and are not to be used where a better treatment and a deeper and more uniform penetration is required.

As I have already said, I think such methods have a place, and when well confined to their proper place will help our industry. We should be careful to make ourselves well understood regarding their intended use. [*Applause.*]

MR. C. M. TAYLOR: If Mr. Buehler is not convinced by this time that these pictures convey a false impression, I do not know how to put it across. Mr. Brown, I want to congratulate you for coming here and taking such an active part in our discussion. A lot of you do not know who Mr. Brown is. Mr. Hunt tells me just now that Mr. Brown is one of the most enthusiastic investigators of creosoted piling in San Francisco. He goes down under his dock even at night; has been there at midnight investigating the work of the marine borers. He is more than a man of average intelligence by the way he goes into these investigations. If he is wrongly impressed by this movie we have just had, how will the unsuspecting public be impressed?

MR. J. H. WATERMAN: The layman?

MR. C. M. TAYLOR: Yes. It would be well for them not to use those pictures again until they are revised.

MR. J. H. WATERMAN: I object to those ties in that motion picture. They have gone the limit, and then they have gone one more. From those pictures I get the sky is the limit for open-tank treatment. Now Mr. Buehler talks about the Stetson hat. If he will go out and ride on the plains with a cowboy he will find he has a Stetson hat. Why? Because he can whip his horse with it; he can sleep under it and he can put it on his head and keep the sun off, because it is the best hat in the country. Now I would like to have these men show with the open-tank treatment the life that they get out of it. I remember one time it was necessary for me to go into a city where there was an epidemic of a contagious disease, and they gave me a bath in creosote when I went in and when I went out. I said that is what we used to treat ties with. I did not take the disease, but I am sure—I am very sure—that those pictures shown to the average laymen will startle them, and they will say, "Why, look at the money we have wasted! Why do we put so much money in a plant if we can treat ties as nicely as those appear to be treated?"

In Southern Illinois there is a fellow who has an open-tank. I wish you could see it. It is about the length of that table. He buys all the cull ties and worthless ties he can get and dips them in this tank and ships them throughout the land as treated ties. How much longer do they last because he has treated them? They last just long enough for him to get his money for the ties he has sold. I still say, and say emphatically, we must be careful what we endorse in the open-tank treatment.

I saw the moving picture of sills, car sills and decking treatment. How much longer life do they get because they are treated? I can show you car sills and decking treated in 1911 on the C., B. & Q., and not a single piece has been renewed on account of rot.

They have been renewed because they are broken. You mean to tell me you can do that with open-tank treatment. I do not believe it.

Now, I believe the way they are treating the telegraph poles is all right. I believe it is all right to treat fence posts with the open-tank treatment, but you have gone the limit, man. Where are you going to stop? The next time we come here we will see a great bridge treated with the open-tank treatment, perhaps. Why not? Why not build a bridge with fir, and then go out and spray it? How much longer would it last? Just about as much longer as it would if you put hot water on it.

Now, one thing more. He speaks about cross-arms. A man came to me and wanted to know if we would not treat cross-arms for him. I said: "What do you want your cross-arms treated for? Your present management will change in 15 years, will it not?" He said: "I believe it will." "Well, the cross-arms you have (Oregon fir) will last 25 years. Why do you want them treated?"

The paving-block industry of this country has practically been ruined, because many of the blocks were improperly treated. I can take you to many cities where the women would mob you if you go there and attempt to sell wood-paving blocks. Why? Because they were improperly treated.

MR. R. F. HOSFORD: I just want to reinforce one thing that Mr. Taylor started to bring out. Speaking not as a layman, but more or less as an expert on the brush treatment—I think I may claim to be that—the spraying and brushing in the pictures gave me the shivers. It ought to be preached on such treatments that the measure of success is not how much you can cover with a gallon of creosote, but how little. The measure is the quantity of creosote you get into the wood on a small area, not how much area you can cover.

And just one other thing that has come up on the side in the discussion, that is the matter of cross-arms and treating them with 12 pounds. The cross-arms that are treated with 12 lbs. are mainly sap loblolly pine. If anybody thinks they will last 15 years if they are not treated, I think he is mistaken, and the reason why they get 12 lbs. is that they have to be made from the green wood and we have not yet any method of using less than 12 lbs. of creosote successfully to get the necessary penetration.

MR. WALTER BUEHLER: Mr. President, I am certainly very thankful for all this instructive criticism. I would like to ask Mr. Waterman a question. If you were operating, Mr. Waterman, a railway located where there is timber, but where pressure treatment was not available, would you advocate the use of ties untreated rather than an open-tank treatment?

MR. J. H. WATERMAN: It all depends where the ties are you can get.

MR. WALTER BUEHLER: That is the point. It all depends on where it is located, and what the conditions are. There are conditions where that would be very advisable. There are other conditions where it would be extremely inadvisable.

Now, as to paving blocks. I want to corrrect the impression that Mr. Waterman has given of the failure of paving blocks throughout the country. I believe it is a very broad statement to say there has been a failure of creosoted blocks throughout the country. It can be attributed more to the method of construction and the misuse of those blocks after they are received on the job than to the character of the treatment and character of the preservative used on the blocks. You have in the city of San Francisco a condition where paving blocks are in bad repute. I believe you cannot blame the creosoting companies in this locality for bad treatment for the reason of those blocks being in bad repute. You must blame the engineer; you can blame this Association for not educating the engineer in the proper way to use those blocks after they are treated, rather than to lay the blame to improper treatment of the block.

THE PRESIDENT: Is there any further discussion? If not, we will ask Mr. Taylor to read a paper by Mr. E. F. Hartman descriptive of a process used to treat pile butts in place.

MR. C. M. TAYLOR: This is a paper that was prepared by Ernest F. Hartman of New York to show the possibilities of the treatment of butts after driving. His original proposition was to take care of untreated piles that are driven in fresh-water and that would have probably 6 ft. or 8 ft. above the water-line which would be untreated. His idea was to treat those butts down to the water-line in order to give longer life. As it developed further he got the idea that it would be a good proposition to use that same scheme on treated piles after they had been cut off before the cap was placed.

LOCALIZED PRESSURE TREATMENTS

By Ernest F. Hartman

"Heads of piles have necessarily to be cut off after driving. This exposes the heartwood, which the creosote oil has not penetrated."

This quotation from the paper on "Twenty-three Years' Experience with Creosoted Timber and Results," by Mr. J. C. Haugh, presented at the first annual meeting of this Association (1905), may well serve as an introduction to the subject of this paper.

In discussing another paper before the American Society of Civil Engineers the same author remarked, "the failures of piles on structures with which the writer is familiar can be attributed to neglect to protect the heads of the piles."

That interest in the subject has been growing will become evident by referring to more recent PROCEEDINGS of this Association.

Mr. Ridgway in his report on creosoted piling in the Galveston Bay bridge of the Santa Fe Railway states on page 195 of the 1914 PROCEEDINGS, "sufficient of the butt of the pile was cut off after driving to expose the untreated center of the stick, and in consequence decay has started."

In the 1915 PROCEEDINGS, on page 302, Mr. Christian states "this pile was treated with 12 lbs. of oil, and if 1¼ inches had been bored through the center for 12 inches or more, and this filled with hot oil 2 or 3 times the first year, this part of the pile would have been as solid as the 2 sections, one end view and one standing, shown in figure No. 7 which is part of the same pile at the mud line."

In 1917, in a talk on "The Bad and the Good in the Handling of Wood," Mr. Geo. E. Rex cites improper uses of creosoted wood. Just one quotation about a creosoted pole: "yet the man has taken a creosoted stick and sawed it in two, and left the exposed heartwood turned up to the sun and rain, an ideal condition for all the decay that is going." Near the close of his remarks Mr. Rex emphasized his belief in the need of an unbroken antiseptic zone by stating "there is not a man in the house that can afford to see and allow a single stick of creosoted material sawed after treatment and not make a kick about it."

In considering this subject it is well, however, to recognize also the demand in fresh-water sections and in tide-water free from marine animalculæ. This is, perhaps, best described in the paper by Mr. Cherrington presented at the Twelfth Annual Meeting of this Association, and which is sufficiently illustrated to emphasize his statement that "before going into the subject further, it may be of interest to note here that the decay of pile (except in warm sea-water where it is attacked by marine borers below the waterline) will, without exception, originate at the wind- and water-line. With the exception of a short distance above and below this line, the balance of the timber will remain solid and sound for many years. But that portion subjected to alternate wet and dry conditions, will rapidly deteriorate in strength and usefulness. Similarly, telephone or telegraph poles decay rapidly only at the ground-line, except in very warm or moist climates, because that portion of it in close contact with the soil will continually absorb moisture. The photographs here exhibited demonstrate very forcibly the activity of decay of piling at the wind- and water-line, in waters free from sea borers."

It will be evident at once that if we meet the conditions described by Mr. Cherrington, that is to say, if we can successfully treat the top of a pile after it is driven and framed so as to give a thorough protection of the exposed surface, we will likewise be able to give a reinforcing treatment to the top of framed creosoted piles. Obviously, a lighter treatment will be required in the case of creosoted piles, since it will only be necessary to replace the treatment that has been cut away, and to insure that there will be no unprotected parts in our creosoted piles. To see to it that every part of our creosoted pile conforms to the specifications laid down by the builder of "that Wonderful One Hoss Shay."

Let us now briefly consider an actual case in New York City. Piles were to be driven, then cut to grade, and the tops framed to form a tennon to which the superstructure or decking was to be secured. The waters where these piles were to be driven contained no marine borers so that the only portion requiring protection was from mean-tide to the upper end of the pile, a distance of perhaps 6 feet. Many of these piles were to be 40 ft. in length, or longer, and if treated by the ordinary methods all preservative injected into the 34 ft. or more below mean-tide would be wasted. As an illustration, take piling with 16-inch butt diameter, tapering 1 inch in 5 ft., exposed 6 ft. above mean-tide, and let us calculate the per cent. of the volume unnecessarily treated in ordinary creosoting:

Length Lin. Feet	Volume Requiring Treatment Cubic Feet	Total Volume	Volume Unnecessarily Treated	Per Cent Wasted Treatment
30	7.76	28.13	20.37	72.4
35		30.60	22.84	74.6
40		32.57	24.81	76.2
45		34.11	26.35	77.3
50		35.26	27.50	78.0

From this table we see that in this case, between 70% and 80% of the treatment we pay for is of no use whatever in the preservation of the pile, so that straight creosoting would be decidedly wasteful.

The collapse of a number of buildings, notably in Chicago and New York, has been directly traced to the failure of foundation piles, due in most cases to a change in ground-water, and there are doubtless other adaptations for the cap method of treatment unknown to the author.

The experiments to be described, while originally limited to meet the conditions first indicated, soon demonstrated that the tops of piles could be successfully creosoted to almost any distance by the use of the cap method of treatment. For these reasons the balance of this paper will proceed on the theory that we are treating piles not previously creosoted.

In the case of piling it is practically impossible to cut timbers to proper length and do such cutting, notching and framing as may be necessary before the timber is treated. The result is that when treated timbers are sawed off to the proper grade, and where they are framed to receive other timbers, considerable quantities of well-treated wood are cut away and wasted and the cut surfaces which are most susceptible to decay are frequently left without treatment of any kind, the outer or treated portion having been cut away.

This fact was realized at an early date and numerous systems and devices have been developed in attempts to localize treatment to certain portions of a timber and leave other portions untreated and to apply pressure treatments to timbers after they are in position cut to grade and framed.

Probably the earliest attempt at a solution of these difficulties is found in a crude apparatus patented in the United States in 1867 by Mr. W. B. Smith. This apparatus consisted simply of a rubber tube, or bottomless bag, which slipped over the end of a timber, and was bound tightly to it by a cord or strap. The sides of the bag were supported to form a reservoir into which the preservative liquid was poured. The pressure due to the head of liquid (about 2 ft.) was found sufficient to force the liquid through several feet of freshly-cut timber. With this crude beginning various schemes have been tried out, none of which has had any wide use or practical success.

In all of these devices or methods one or more of the following list of defects are to be found:

(1) The timber must be freshly cut.

(2) The end of the timber to which pressure is applied must be accurately squared or cut to some special form.

(3) The apparatus is too bulky to be portable so that treatment cannot be applied to timbers in place.

(4) Holes are bored in the timber which reduce its strength, and from which the treatment enters and passes

through the timber in well-defined longitudinal streaks following the grain of the wood.

(5) The timber must be of comparatively short length.

(6) The timber must be perfectly round or rectangular. (No reentering angles or grooves.)

(7) The timber must be of uniform diameter to allow the apparatus to pass over the end.

(8) The timber must all be of the same size, or a different apparatus must be used for each size.

(9) The treating apparatus carries a sharpened annular ring which is driven, or forced, into the end of the timber so that the outer portions are not treated.

(10) The bark must be removed.

(11) Both ends of the timber must be free.

(12) The seal is of material that can be used only with certain preservatives.

(13) The seal is difficult to make tight, and considerable waste results through leakage.

(14) The apparatus requires too much time in adjustment to the timber.

(15) Cap is of rubber, leather, or fabric, and will not stand much pressure.

(16) The seal consists of a material that must be frequently removed, or replaced, at considerable expense.

(17) The sealing gasket has one or more joints which are hard to make tight.

(18) The seal is of plastic material, or cement, either not readily obtainable under ordinary conditions, or too expensive to be practicable.

The above list of defects give some idea of the state of affairs when in April, 1914, the experiments covered by this paper were undertaken.

Enjoying excellent library facilities, a search was made for past and contemporary investigations including all United States patents on wood preservation. The result indicated that none of the methods then known could be practically applied. It is of interest to note the large number of patents issued based on the principle covered by this paper, not only for the injection of preservatives, but also for coloring matter, dyes, stains, etc.

It is well to bear in mind that this study represents industrial research, and that in consequence factors were changed whenever warranted or thought advisable.

After considerable study it was decided to enclose the end, including the framing in an oil-tight cylinder, or cap, which should extend down as far on the pile as treatment should be required. The space between the pile and the lower open-end of the cylinder was to be closed by a seal of some sort, and then the preservative was to be introduced into the cylinder and pressure applied to force it into the pile. From the first it was anticipated that the greatest troubles would be found in making a tight seal. It was determined to try a ring, or collar, with a "Z"-shaped cross-section made in sections so that it could be drawn tightly around the pile by bolts, forming an annular trough into which packing could be placed in or against which the cylinder could be tightly held by bolts or dogs.

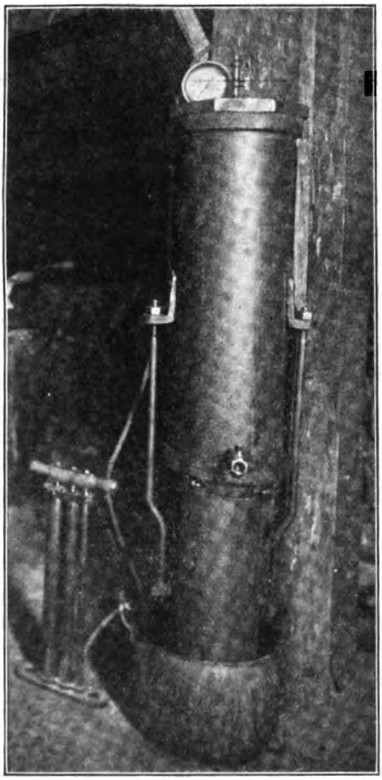


Fig. 1. First Experimental Cylinder Used.

Plans were drawn up and an experimental cylinder 9 inches in diameter and 30 inches long was made. A quantity of pile ends, about 4 ft. long, were obtained, and early in 1915 experimental work was actually begun. At first the cylinder was poured full of preservative and then air-pressure was applied by means of a hand-operated automobile tire-pump, with which pressures up to 100 lbs. per square inch could be obtained.

Various materials were tried in the search for a suitable seal, among them, cotton-waste, hemp, leather, and rubber. Finally the trough-shaped collar was poured full of plaster of paris, and the lower edge of the cap was set in this. The plaster hardened in from 2 minutes to 5 minutes, and proved effective from the first trial. In this connection it might be worth noting that the Bureau of Standards of the Department of Commerce states that: "a recent sample of this material was found to give, at the age of 24 hours, a compressive strength of 1,000 lbs. per square inch. With reference to the use of hemp, or similar materials, as a reinforcement in plaster of paris, we see no reason why hemp could not be

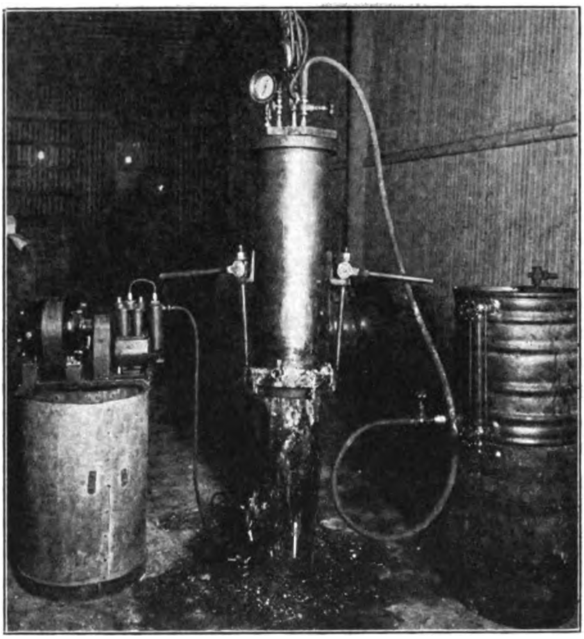


Fig. 2. Cylinder With Dogs Operated by Cam-Levers. Pressure on Oil in Separate Storage Tank.

used in the same way that hair and wood fiber are used for reinforcing the tensile strength of wall plasters."

As experimental work proceeded various changes and additions were made to overcome defects in the original design. A steam coil was placed in the cylinder to heat the oil as it entered the timber. The cylinder was first held to the collar by means of dogs which slipped off occasionally until a ridge was placed beneath the outer edge of the collar with which the dogs engaged. These dogs were drawn tight by means of cam-levers which proved unreliable so that the stem of the dog was extended to a perforated bracket at the top of the cap and drawn in place by a wheel nut.

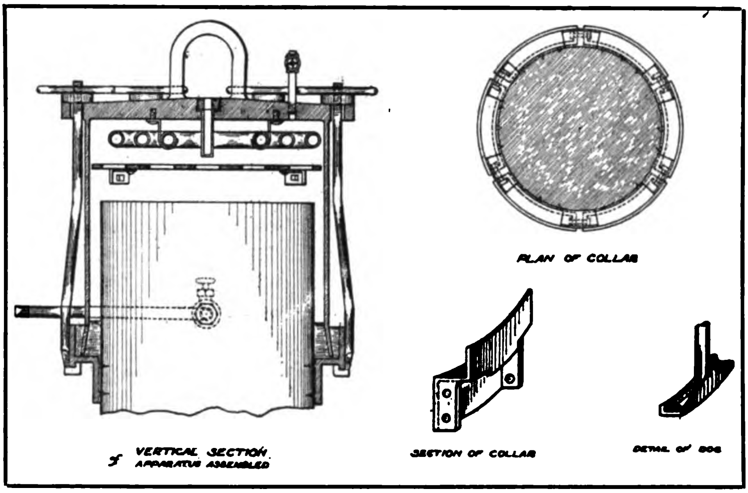


Fig. 8. Height of Cylinder, 18 Inches. Thermometer Well in Cylinder Shown.

Various types of collar were tried. The first one was simply made in halves, held together by bolts. This was found to be too rigid, and collars of greater numbers of segments were tried. One having 17 sections, mounted on a chain, was found to be too flexible to give a rigid foundation for the plaster. Finally a collar of 6 sections, held together by bolts, was found in every way satisfactory and sufficiently flexible to take care of the ordinary irregularities found in piling. The portion of the collar coming in contact with the pile was provided with short spikes to prevent slipping under pressure, and the joints of the trough were covered by loose pieces of metal, or shims, to prevent the plaster from running out before hardening.

At first it was decided to make the cylinder, or cap, long enough to include the entire portion of the pile to be treated. Experiments showed, however, that treatment extended beyond the limit of the cylinder, so a cap was finally adopted that was only long enough to include the end of the pile and give a firm hold for the collar.

Other minor changes were made so that the cap as it now stands is as shown in the accompanying sectional drawing. A cap of this design fitted with dogs, wheels, and steam coil, and large enough to accommodate piles up to 17 inches in diameter can readily be handled and placed in position by 2 men.

In the experimental treatments made up to the present time no particular attempt has been made to arrive at factors from which the time required to obtain any given absorption might be predicted. The experiments have on the contrary been planned to cover as wide a field of variation in conditions as possible.

Our greatest lessons are learned from failures, and so the data here given represent actual data gathered during the experimental work covering conditions met with in actual practice. This is well to bear in mind.

Following is a brief summary of a few of the typical experimental treatments:

Dry Timber

Dry shortleaf pine was used and no difficulty was encountered in forcing oil into the wood. Treatments lasting from 10 minutes to 6½ hours were made, and absorptions varying from ½ gallon to 4¼ gals. on piles 7¼ inches to 8½ inches in diameter, and from 3 1/3 gals. to 10 gals. on piles 16 inches and 17 inches in diameter, were obtained. This includes all runs, some of which, owing to local conditions, gave exceptionally high or low results.

Chart "A" represents the average results from normal treatments of pile-sections approximately 4 ft. long that had been stored in a cellar and were thoroughly seasoned, using the second cylinder developed. Since the absorption of oil through lateral surfaces was practically negligible the curve is based on the absorption in gallons per square foot of end surfaces. These conditions would be comparable to those of poles and posts air-seasoned in open sheds, or buildings.

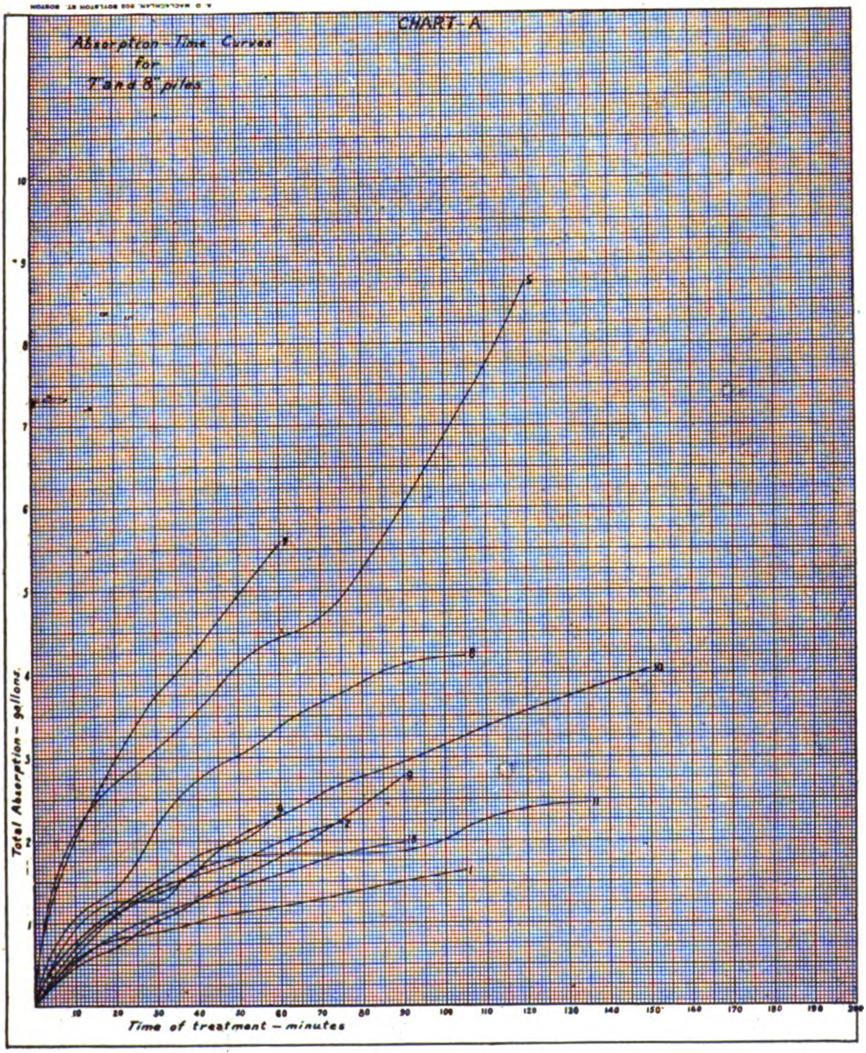


Chart A. Average Result of Absorption With Time Data.

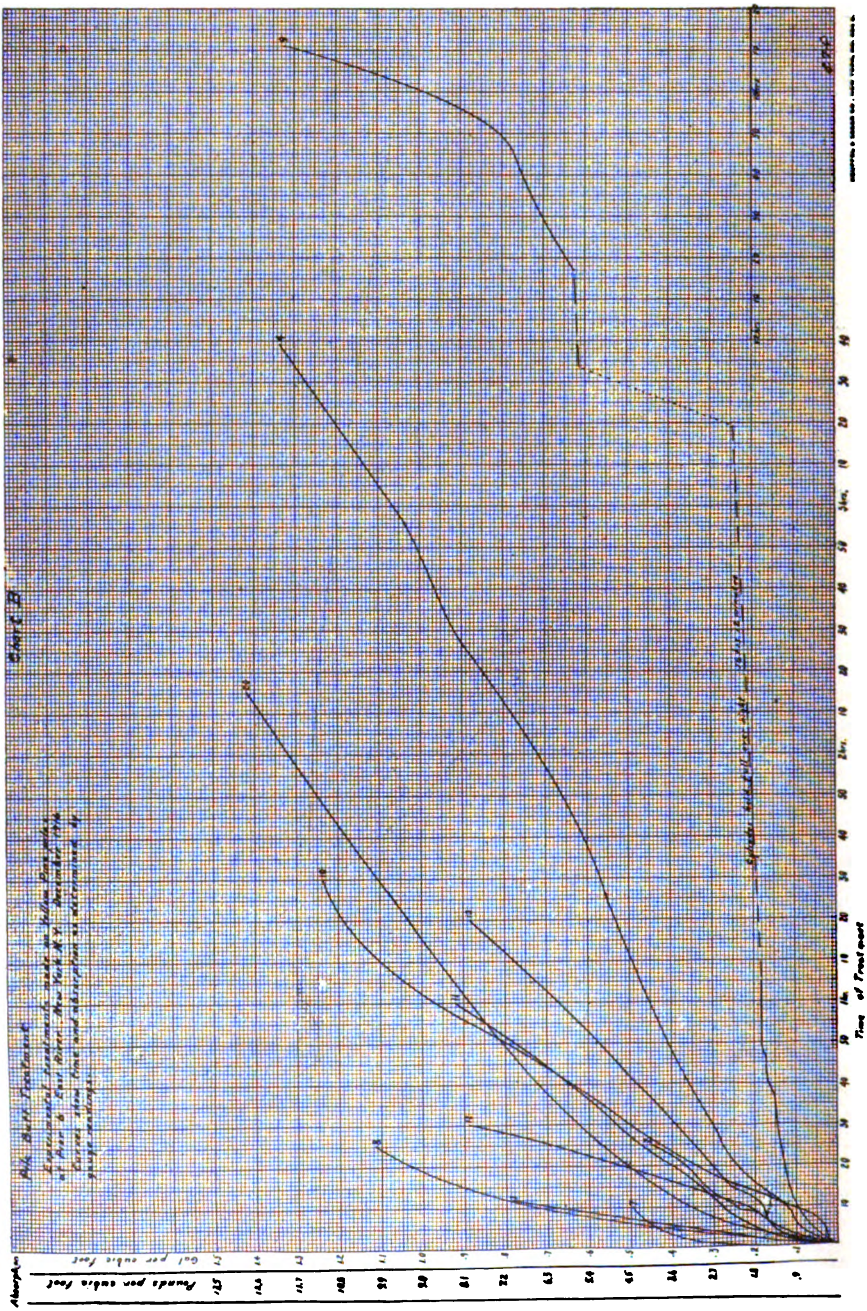


Chart B. Average Result in Actual Field Operations.

Chart "B" represents average absorptions from normal treatments of piling in an actual structure, and are comparable to the results to be expected in practice in marine work where the piling is not floated to the job.

Data on a like number of runs with the equipment finally developed would obviously yield more concordant results. Changes in the temperature of the preservative, and in the pressure, account for all of these variations. This then will account for the great variation in the slope of the curves in both charts.

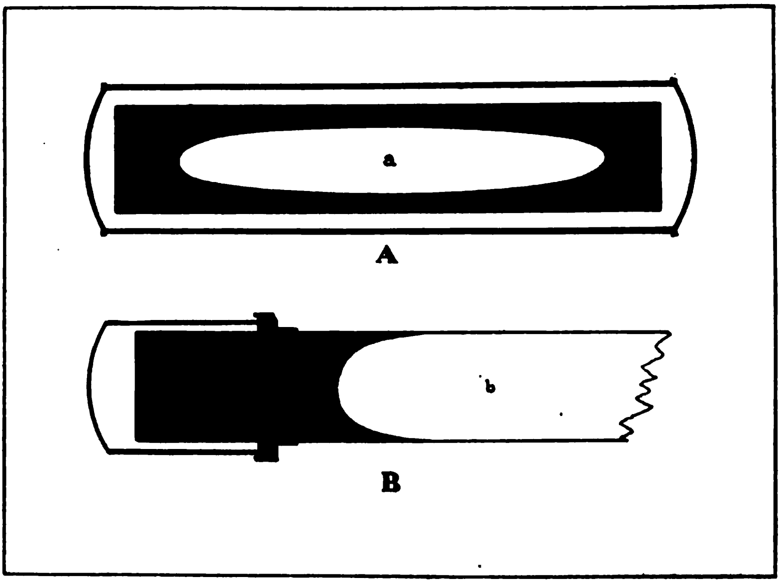


Fig. 4. Effect of Compressed Air in Retort and Cap Method of Treatment.

An examination of these curves reveals in a very conclusive way the essential difference between this method of treatment and ordinary creosoting.

Similar curves of ordinary creosote treatments show a gradual reduction in absorption per time unit as the treatment progresses whereas in this method no such reduction is noticeable, the absorption per unit of time proceeding at an almost uniform rate after the first 10 or 20 minutes of treatment. The reason for this difference becomes apparent upon examination of the accompanying diagram in which "A" represents a longitudinal section of a timber treated by the ordinary method, and "B" a similar timber treated by the localized, or cap method.

In "A" the timber is completely surrounded by the preservative under pressure, and as the liquid enters the wood it encloses a pocket of air "a" in the interior of the timber. It is quite obvious that as the liquid is forced into the wood this air is compressed and the injection of the preservative proceeds against a gradually increasing internal pressure. This continues until the internal pressure is equal to the external when no further absorption or penetration can take place without increasing the external pressure. Furthermore when the external pressure is released the included air expands and forces some of the absorbed preservative out of the timber—the kick-back. From this it may be concluded that by the ordinary methods saturation treatments, except in the extreme outer, or surface, portion of the timber, is quite impossible, and this has been proven experimentally.

In "B" on the other hand the pressure is applied only at the treated end, and the air "b" in the timber is simply driven ahead of the preservative, leaving the timber at the other end. There is consequently no limit to the longitudinal penetration of the preservative except through the mechanical clogging of the passages through which the preservative enters the wood. The experiments here described have shown this to be practically negligible with the ordinary preservatives now in use. Furthermore, on releasing the pressure at the end of the treatment there is no reaction to eject the absorbed preservative from the timber, and the treated portions of the wood are left in a condition of saturation.

Green Timber

Three small piles, practically unseasoned, were treated, and while the preservatives entered much more slowly, satisfactory absorption was obtained. The rate of absorption was approximately one-third of that obtained in the perfectly dry piles, and 0.6 of that obtained in the actual marine work. During the treatment the sap and moisture appeared in checks, and at the exposed end of the timber, and continued to exude as the preservative was forced in at the other end. Small holes were bored in the lateral surfaces of the exposed portion of the timbers, and from these the water poured in an almost continuous stream.

Wet Timber

In order to determine the effect of floating, or rafting, timbers to the job, three piles were moored to a dock in New York Harbor and allowed to float for 3 days. The water absorbed amounted approximately to two-thirds of the dry weight. When treated it was found that these piles absorbed the preservative more readily than the dry piles, and that during the treatment the water was expelled so rapidly that the entire exposed portion of the pile was covered with froth. This is very well shown in the accompanying photograph of one of these piles during the treatment. Four and one-eighth gallons of oil were injected into the end of this pile in

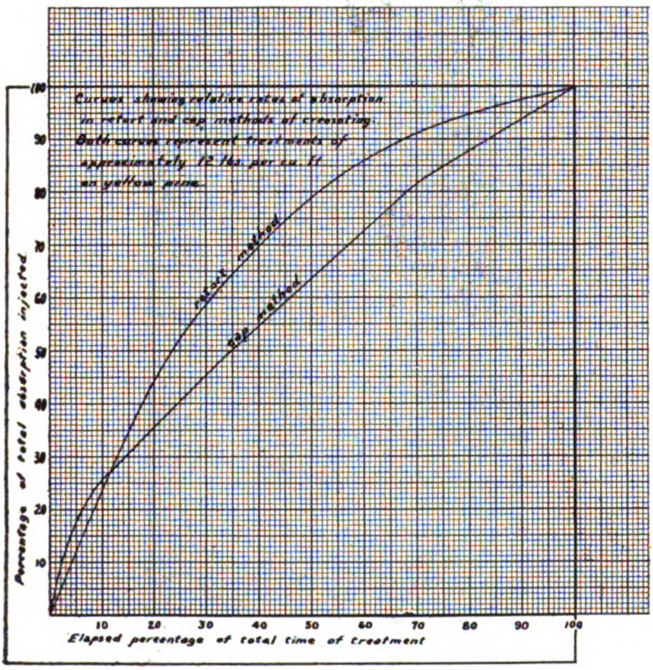


Fig. 5. Actual Difference Between Retort and Cap Method Based on Similar Treatments.

1⅛ hours at a pressure of 50 lbs. per square inch. This is equivalent to 12.15 gals. per square foot of end surface.

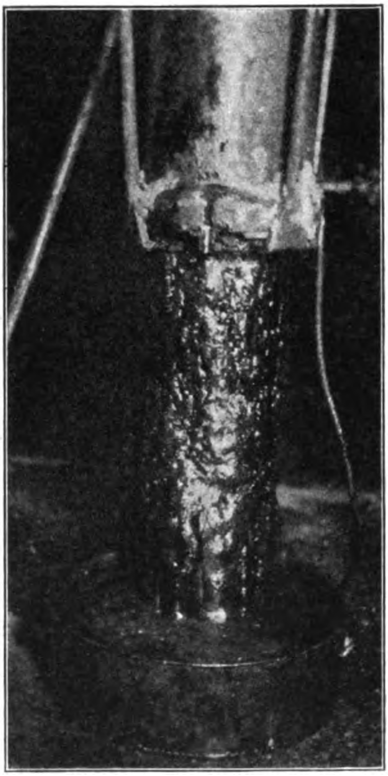


Fig. 6. Water Being Driven Out of a Floated Pile.

The accompanying photograph is of a pile that had been floated in salt-water for 3 days before treatment and stood in salt-water while being treated. The treating cylinder extended approximately one-half the length of the pile shown. Treatment was for 1 hour from end marked "X" with the preservative at 80° C., and a pressure of 35 lbs. per square inch. Pile was cut, dressed and photographed immediately after treatment, the absorption being 2⅛ gals., or 22.7 lbs. per cubic foot.

This, like the preceding photograph, shows a pile that had been floated in salt-water for 3 days before treatment, and was given

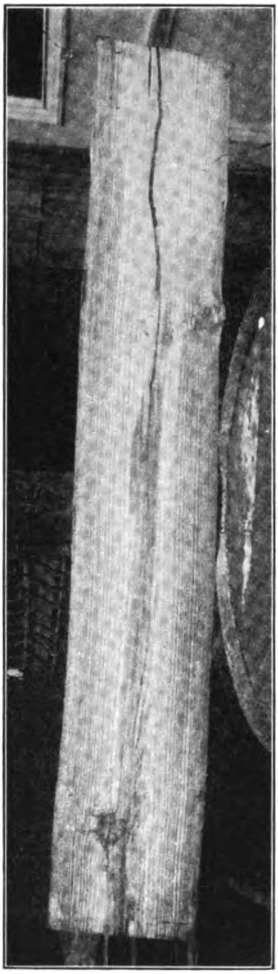


Fig. 7. Pile Shown in Fig. 6 Split at Completion of Treatment.

exactly the same treatment as the previous pile, the cylinder likewise extending to one-half the length of the pile which stood vertically in salt-water for one-half of the length shown from the time of treatment until cut and photographed, which was 10 days after treatment. It will be apparent at once that the penetration

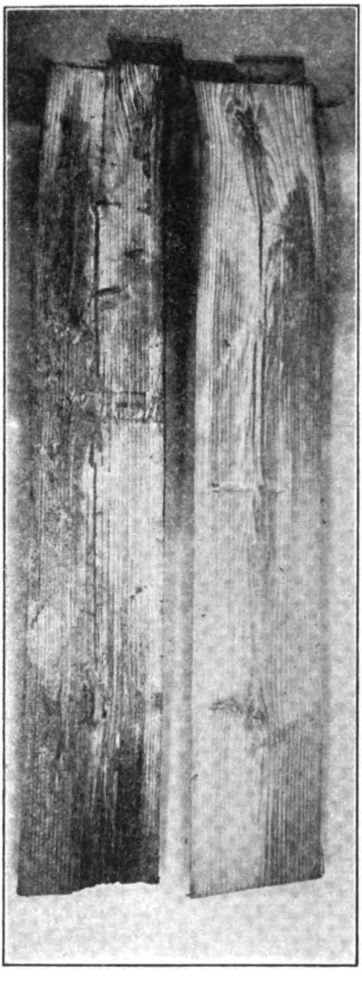


Fig. 8. Identical Treatment as Shown in Fig. 7 Split Open Ten Days After Treatment.

shown on the preceding photograph cut immediately after treatment was not complete.

Bark

The presence of bark on the pile had no appreciable effect upon the treatment, since in this form of creosoting we are relying solely upon longitudinal, or end, penetration. It was found, however, that it was difficult to obtain a tight plaster joint over bark. This was remedied by removing the bark under the collar only, so that the plaster could set in contact with the wood.

Pressure

The effect of variations in pressure during treatment in this process is by no means as great as in the retort creosoting process. As is to be expected, an increase in pressure causes an increase in the rate of absorption, but it was found that on complete runs in which the pressure was held practically constant the difference in rate of absorption between runs made at 35 lbs. per square inch and 100 lbs. per square inch was not as great as that due to variations in the timbers themselves when treated at the same pressure. Fifty pounds per square inch was found to be a good average working pressure, but in practice it is advisable to regulate the pressure to suit the individual timber, adjusting it so as to obtain uniform rates of absorption. It is believed that by this method uniform absorptions may be obtained in every piece and the resulting preservative effect will in consequence be uniform and can be regulated at the will of the operator.

Pile No. 20, shown in the accompanying photograph, was 16 ins. in diameter, and 46 ins. of the top were enclosed in the cylinder during treatment. As is evident from the picture considerably more than 46 ins. of the pile top is shown, and yet the treatment is thorough even at the bottom, showing that it went considerably into that portion of the pile which remained in place beyond the section cut off. This treatment was accomplished in 2 hours 15 minutes, at an average pressure of 57.2 lbs. per square inch. The preservative injected amounted to 0.532 gal., or 4.788 lbs., per square foot of end surface. The pile being cut off close to the water it is readily seen that the treatment extended not only beyond the treating cylinder but below the water-line.

It might be well to note that in practically all of these experimental runs the treatment extended considerably beyond the collar of the cylinder. This was usually evidenced by the presence of oil on the surface by an axe-mark, or where the timber had been cut slightly across the grain, or was intentionally demonstrated by boring holes in the exposed part of the pile during the treatment.

Temperature

The effect of the temperature of the preservative during injection appears to have a much greater effect upon the rate of adsorption than variations in pressure. Increase in temperature of

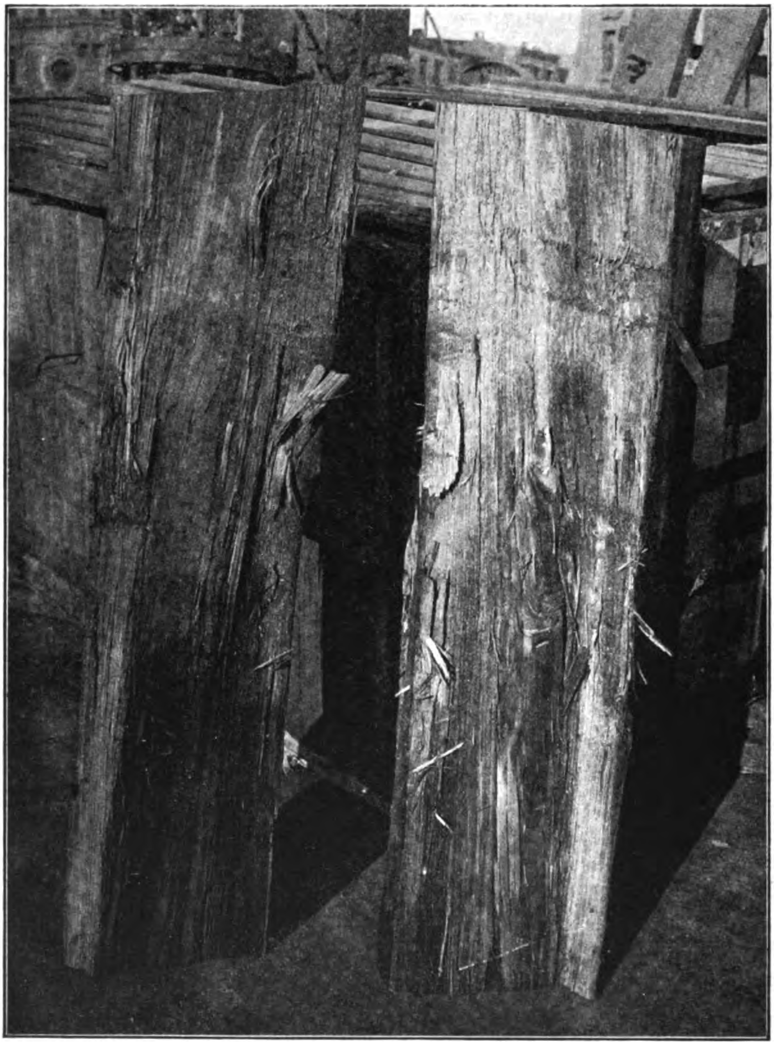


Fig. 9.—Pile No. 20 Split Open to Show the Thorough Penetration of the Preservative.

a few degrees cause a marked increase in the rate of absorption. This was very nicely brought out in the treatment of pile No. 23.

This treatment was started at 4 P. M., and no steam was available at the time for heating the preservative. The air-temperature at the time (December, 1916) was very close to freezing, and this was probably not much lower than that of the preservative. The treatment was continued for 65 minutes, during which time the pressure was gradually raised from 45 lbs. to 100 lbs. per square inch. The absorption during this time was quite uniform, but at the end of the time only 1.35 gals., or 0.856 gal., per square foot of end surface, had been injected. The treatment was then stopped, and the apparatus left with the pressure on until 9:25 A. M., in which time the pressure had, of course, dropped to zero. Steam was now applied to the oil in the cap. The temperature was raised to 79° C., and in 56 minutes, using a pressure of 50 lbs. per square inch, 5.83 gals. were injected, or 3.70 gals. per square foot of end surface.

Since the preservative used was one that was perfectly limpid at the lower temperature it is to be presumed that this result is due to the effect of the heat upon the wood and the saps and resins contained in the wood rather than upon any reduction in the viscosity, or density, of the preservative.

This particular run will also indicate the character of the bond secured, and appears to establish the correctness of the design of collar and the plastic material used.

In the light of certain previous research work done by the author jointly with Dr. A. L. Dean it is well to hold the temperature within certain limits and beyond which a rise in temperature will not increase absorption.

Empty-Cell Treatments

By the cap method these may be obtained by injecting the preservative under pressure, then releasing the pressure, emptying the cylinder, and applying either a vacuum, or air, pressure.

In the first case, the surplus preservative is drawn back into the cap, and can be recovered.

In the second case, the preservative already injected into the timber remains there, but is driven further into the stick ahead of the injected air, causing still deeper penetration and greater distribution of the preservative. The latter is, of course, the easier

and less expensive method, since the same air-compressor is used for both stages of the process, no vacuum-pump is required, and the amount of preservative originally injected is considerably less, resulting in a saving of time and power.

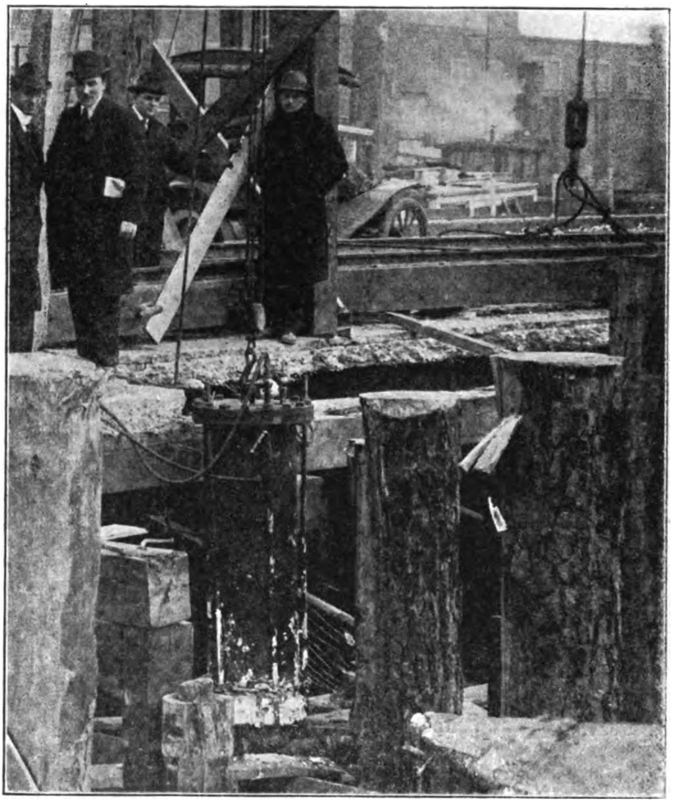


Fig. 10. Cylinder Used for All Treatments Shown on Chart B.

All the treatments shown on Chart "B" were given with the cylinder shown in this photograph. The treatments were conducted at Pier 6, East River, New York, during the widening of the pier for the New York Barge Canal Terminal.

From the experience gained in making these experiments the cap, or cylinder, reproduced by this photograph, and of which sectional drawings have previously been shown, was developed.

From the foregoing it would appear that the localized, or cap system of creosoting, possesses advantages especially in adaptability, efficiency and relative cost.

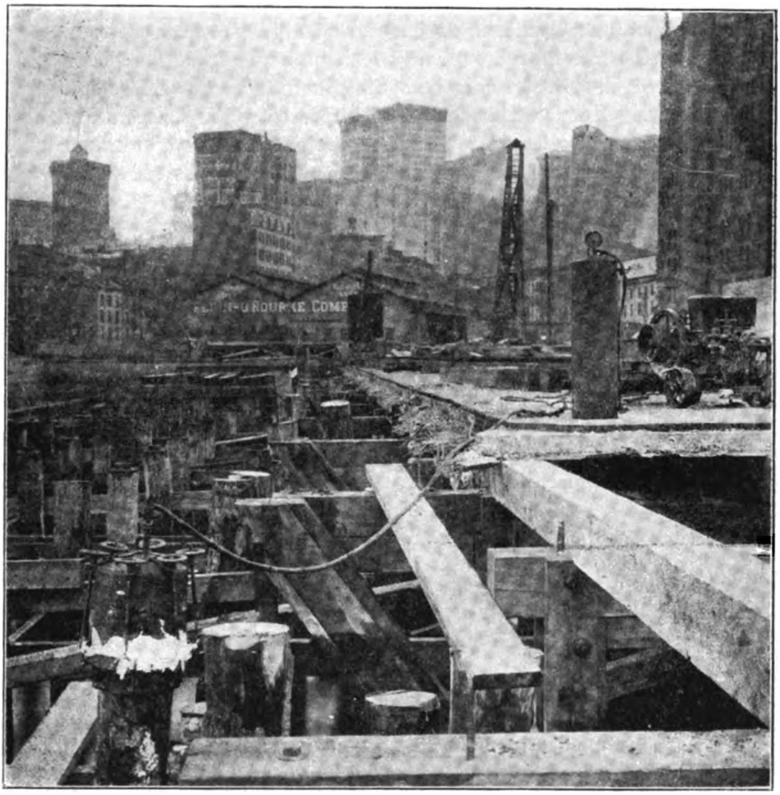


Fig. 11. Showing the Cap as Finally Developed with Pressure—Tank and Air Compressor.

Fully realizing that the ultimate adaptations of this method cannot be foretold it is interesting to speculate on some of the possibilities. As an example, we may consider the harbor conditions in San Francisco, with the sudden appearance of the teredo in water, where it was formerly deemed unnecessary to use creosoted piles.

It might have been possible to creosote all such piles as had the end free, or whose ends could have been exposed.

Adaptability

The adaptability of the method to timber of all sizes and shapes requires only the use of caps, or cylinders, of suitable size, and collars of appropriate design. It is a portable apparatus, and as many caps, or cylinders, as desired can be simultaneously operated with 1 air-compressor, using 1 oil-pressure tank, or a separate tank for each pile. Long seasoning is not essential to efficient treatment. Green, waterlogged, or unpeeled, piles offer no difficulties. It is as applicable to telephone-pole butts as to piles. Full- or empty-cell treatments may be given with any desired preservative.

Efficiency

The efficiency of a treatment after all framing, boring, adzing, or cutting, and giving any desired depth of penetration or absorption of preservative is too evident to require detailing. Those interested will find some definite comparable data on penetration and absorption in ordinary creosoted piling by referring to the paper of Mr. Allardyce and that of Mr. Allerton in the 1911 PROCEEDINGS of this Association. See also "Penetration of Creosote Oil in Round Piling" by Mr. R. H. Rawson presented last year.

Cost

The cost of the treatment, based on the experiments here described, bids fair to offer no obstacle to its use for supplementary treatments of creosoted piling after these have been driven, and framed. For the treatment of the exposed part of piling in fresh water, or water free from marine borers, the cost would appear relatively low for the protection afforded. An empty-cell cap treatment of pole butts should compare favorably in cost with the methods now in use. It is certain that the loss due to evaporation would be obviated. The low cost of the equipment makes this method of interest for foundation piles, whether for trestles or buildings.

This paper is submitted as representing industrial research to serve as a basis for future progress.

These curves illustrate the actual difference in the 2 methods of treatment. The data for both curves represent treatments of nearly 12 lbs. per cubic foot, and both are on yellow pine.

On referring to the retort curve it will be noted that the absorption was very great at first, nearly 80% of the oil being injected in the first half of the treating period, after which it falls off rapidly so that during the last 10% of the time only 2½% of the absorption takes place.

From the curve for the cap treatment it will be noticed that after the first 10% of the time the absorption per unit of time was practically uniform, remaining so to the end of the treatment. This demonstrates that there is no refusal point in the cap method of creosoting, and as indicated by results obtained in the experiments additional oil injected will simply come out at the other end of the pile.

In the case of the retort curve the pressure was constantly increasing during the treatment from nothing to 145 lbs. per square inch, while in the cap method after the first few minutes the pressure remained practically constant and rarely exceeded 60 pounds.

(Lantern slides were then shown with comments by Mr. Taylor.) [*Applause.*]

THE PRESIDENT: Are there any remarks on this paper?

MR. A. A. BROWN: I do not want to be a pest, but I came here particularly to hear this paper, and to me it is a very impractical proposition. It is impossible to wait 3½ hours to cut off each one of those piles. I think we have to look further for something that is practical in use.

THE PRESIDENT: The paper, of course, is submitted as information, as a method, and accepted by the Association as such.

MR. A. A. BROWN: The point that I wish to make is this, that it is something very much needed. We are cutting off piles every day and capping them immediately. They are subjected to rot and attack by marine borers, and if it is possible to develop something that would be effective it would certainly be very useful from an economic standpoint.

MR. GEO. M. HUNT: Mr. Chairman, I think Mr. Brown has brought up a point to which this Association has not given much attention. We all know when you cut off the end of a pile, and put a cap on you offer a chance for the pile to decay. Even if you do not put a cap on it, the pile will decay inside the treated area, because untreated wood is exposed. We have known that for a long time, yet we have never recommended any standard way of protecting the top of a cut-off pile. Could not this Association take some action during the coming year to develop some such recommendation? I should like to move that the Executive Committee, if they see fit this year, appoint a committee to bring in definite recommendations at the next convention for the protection of such piles.

THE PRESIDENT: Is there a second to that motion?

MR. A. A. BROWN: I think Mr. Hunt would do well if he could include in that motion a recommendation that you make a very thorough study as to the methods of handling the pile from the time it is treated until it is finally driven, following it through the entire route, and endeavoring to standardize the development of the best possible methods of handling and using the piles, not only the cutting off, but the handling. I believe it would be very helpful to the man who is actively on the job. We are just partially solving the problem when we treat the pile; if we are going to treat it, put it into use, and it is useless, it is going to bring the treating industry into disrepute.

THE PRESIDENT: Mr. Hunt, will you accept that amendment?

MR. GEO. M. HUNT: The point which Mr. Brown brings up is, of course, a very necessary thing to study, but it is too big a job for one committee to complete in a year. One of the recommendations for the San Francisco Piling Committee during this coming year is the study of that very thing: how can Douglas fir piling be handled and used in order to damage it the least, and I think the Association has the right to expect that Committee will next year bring in some definite recommendations. This other thing might be included, and covered by that Committee, or it might be handled separately. I think it ought to be handled separately, because it applies not only to marine piling, but also to land piling and railroad bridge work. It is an important thing, and it is a unit in itself which one committee can handle and which we can expect to standardize in a short time. The larger study which Mr. Brown mentions, and which is badly needed, is of such magnitude that you cannot hope to get a complete report next year, or to get your ideas accepted. It is a project which will require several years. I have no objection to having this project of protecting the tops of the piles included in the Marine Piling Committee's work, but it seems to me the quickest way to get results would be for a committee to be appointed with that one duty.

MR. J. H. WATERMAN: I second Mr. Hunt's motion.

THE PRESIDENT: Are you ready for the question? It has been moved and seconded that the Executive Committee appoint a special committee to develop a satisfactory standard practice to protect the tops of treated piles. All in favor respond by saying "aye"; contrary, same sign; it is so ordered.

If Mr. Waterman, who is the General Chairman of the Committee on Plant Operation, will come forward, we will ask Mr. Edwards to show his lantern slides on the perforating layouts.

MR. J. H. WATERMAN: Your Committee No. 6 on Plant Operation was instructed to report on first, Peeling; second, Adzing, Boring and Perforating Layouts; third, Car Loading; fourth, Switch-Tie Yards. Mr. Edwards, Chairman of Committee No. 6-2—Adzing, Boring and Perforating Layouts, will give his report.

(Mr. Edwards then presented a number of lantern slides accompanied by explanation and comments on the slides.)

REPORT OF COMMITTEE NO. 6-2—ADZING, BORING AND PERFORATING LAYOUTS

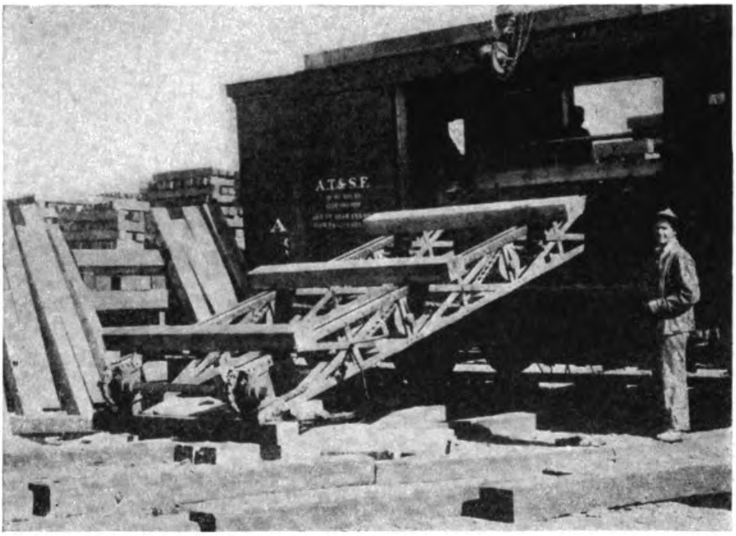
To the Members of the American Wood-Preservers' Association:

Adzing, boring, trimming and branding operations are performed on railroad cross ties for the purpose of making them more suitable to their mechanical requirements and provide ways for better chemical treatment. Adzed rail, or rail-plate surfaces, present perfect plane bearings on all ties, either sawn or hewn, that better support the rail. Boring assures perfect gauge, increased spike-holding power, and permits the preservative to enter and thoroughly penetrate the ties at the point where the chemical treatment is most required. The ends are trimmed for appearance and inspection and branded for identification.

Machines for doing this work may be assembled in a portable car that the plant can be moved to the ties, or erected on a permanent foundation and the ties delivered to the fixed location. Both types of installation have their advantages, but the one best suited to local conditions is more or less readily determined by the yard layout, number of ties to be considered, and available methods of handling ties.

The equipment to be included in an installation must be determined from a careful study of the kind of ties, means provided for handling them, method of disposition after machining, and disposal of the refuse. A brief outline of some existing plants will doubtless best describe the developments that have been made, and point out conditions that must be taken into consideration when the best type of installation for a definite point is to be decided.

The Atchison, Topeka & Santa Fe Railway used the first of the early American-made machines for this work. Their first plant was designed for adzing and boring only. It was mounted in a box-car, and its power supplied by a 45-H. P. gasoline engine. A small shavings exhaust fan collected the chips and borings, and delivered them through a cyclone dust collector into the open beneath the car. In-feed conveyors were provided for carrying the ties from the ground to the machine. Ties entered one side of the car, passed through the machine, and were permitted to slide down skidways from the opposite side of the car from where they were disposed of by hand labor.



Feeding Ties to Machine, Mounted in Santa Fe Car.

The gasoline engine providing power for driving the machinery was also geared to one of the car axles, and fitted with reversing gear and clutch, making the car self-propelling that it could move short distances under its own power. An automatic machine for grinding the knives for the adzing heads was installed in the car, together with work benches and the necessary hand tools for the maintenance and operation of the equipment.

The Northern Pacific Railway's first plant, built shortly after, was almost a duplicate, but with a few changes that seemed to be necessary from experience had with the first one, but it was not until after this plant, as well as a second one, built for the Santa Fe, had been operated for some time that real improvements began to be made, and though these were practically all mere detail matters they were of vital importance.

Combining the functions of adzing and boring in one main frame made a rather complicated machine, difficult to adjust, repair, or even operate. The necessity for gasoline engines of more rugged design and greater horsepower, with a cooling system of greater capacity and efficiency than the ordinary oversize radiator, as well as a better means of starting the motors, was proven. The rather small shavings exhaust fans were forced to give way to fans having a capacity that, to the engineers in charge of the development, seemed beyond the requirements.

In the boring machine it was found absolutely necessary to provide steel templates for guiding the bits. Both because they would otherwise run out and bore crooked, and were not always set in exactly the right gauge by the operators. In adzing the vital necessity of a compensating or equalizing device that would automatically control the depth and thus cut both straight and crooked ties as deep but no deeper than necessary, was made plain. In the early machines the maintenance of leather belts running at high speed and under severe tension was a source of annoyance later overcome by the use of silent high-speed chain-drives.

The Santa Fe had 3 and the Northern Pacific 1 of the real early types, and all of these were portable. One of those owned by the Santa Fe was scrapped several years ago, and the second rebuilt, after several years' operation and the successful machining of a great many ties. One of the original machines is still in operation.

It was when the Northern Pacific Railway Company bought their second plant that an attempt was made to save time and labor in the handling of the ties. This machine was fitted with the usual in-feed conveyors, and also out-feed conveyors, arranged to deliver ties direct to tram-cars. These were equipped with an accumulating device, which consisted of tracks arranged to raise and lower by hand-lever that would lift the ties clear of the feed-chains on the out-feed conveyors, and permit several ties to collect thereon while the loaded tram was being removed and an empty one placed in position to load. When the accumulation device was released the collected ties passed on to the tram, the machining not having been interrupted through changing trams. This car was equipped with power-driven capstans, operating a long rope haul which removed the loaded trams to a point some distance down the track where they were assembled into trains for the retorts.

The power-driven rope transmission was also used by the Santa Fe, but this was of their own design, and not a part of the original plant. The Northern Pacific Company's second car was built without a shavings-collecting fan, and the chips and borings were permitted to fall directly through openings in the floor on a large canvas placed beneath the car, this canvas afterwards being hauled away, and the shavings disposed of.

These cars have all been used, principally in tie-yards. They have been placed on temporary-track sections, and ties delivered to their in-feed conveyors by hand-labor direct from the yard piles. After passing through the machine the ties have been carried on out-feed conveyors, or skidways, to the tram-cars. As the tie piles are cleared away the car is moved by its own power to the next pile along additional temporary track sections.

Probably no type of installation will machine ties cheaper than this. The modern machine mounted in a large roomy car, approximately 9½ ft. wide inside and from 45 ft. to 50 ft. long, provided with the best equipment, which includes extra heavy duty engines, refuse removal system, light but strong in-feed conveyors and out-feed conveyors fitted with accumulator and tram-car rope haul, make the cheapest plant so far as first cost is concerned, machines nearly as many ties as the stationary type, and eliminates one handling.

The Pittsburgh and Lake Erie Railroad at Adelaide, Pa., the Delaware, Lackawanna & Western Railroad at Paterson, N. J., the Chicago, Rock Island and Pacific Railroad at Kansas City, and the Philadelphia & Reading Railway at Chrome, N. J., were examples of some of the early stationary installations. The machines at Adelaide, Pa., and Chrome, N. J., were fitted with trim cut-off saws and dies for branding characters in the tie ends, to denote ownership and date of treatment. The object in providing trim-saws was to square up the ends of the ties for general appearance sake and present a true surface for receiving the brand, which consisted of characters 2 ins. high, stamped in the tie ends.

It was soon discovered that the trim-saws fulfilled a duty of far more importance than they were originally designed for, since the freshly cut tie ends disclosed the internal state of preservation not always noticeable from the weathered ends of the ties before trimming. Some ties presenting good external appearance when trimmed ½ in. at the ends show hearts decayed to a degree that it would be wasteful to treat and place them in track, and, therefore, are rejected. So valuable has this method of inspection been found to be that installations have been made of trim-saws alone, and ties trimmed for no other purpose than to clearly disclose the actual internal condition of the heart.

In the earliest of the stationary plants it was found advisable to provide a means of dumping the tram-loads of ties on skidways in front of the machines, since both time and labor were saved by so doing. Two men are required to feed the machines, and as they must handle between 6 ties and 7 ties per minute, place them in proper position for the feed-chains, it is a somewhat difficult matter for them to accomplish their work and maintain the necessary speed, especially when working from the bottom of the tram. Without the use of skidways there is an unavoidable delay when changing trams. Both of these faults are obviated by the use of skidways with capacity for at least 1 full tram-load of ties, and some method of mechanically removing the load from the tram-car to them.

The Pittsburgh Wood Preserving Company installed a tilting track in front of the machine at Adelaide, on which the loaded trams were locked and tilted to an angle that would cause the ties to drop to the skidways in front of the machine. The American Creosoting Company installed an elevating device in front of the machines at Paterson and Kansas City, arranged to wind up chains that lifted the load to the skidways, permitting the tram-car to remain in position on the track. Both methods proved to be successful time and labor savers.

After the first few stationary plants had been erected it was found that commercial tie-yards and treating plants would require machines built with a wide range of adjustment for gauge, since they were receiving calls for machined ties for widths of gauge of from 3½ ft. to 5 ft., and as at this time the idea of combining adzing and boring mechanical details in one frame was being dropped and the machines constructed in independent units the wide range of adjustment was also embodied in the new design. The first installation of this class made was in the plant of the American Creosote Works of New Orleans.

Rather minor details, really of vital importance in the successful operation of stationary plants, must be taken into consideration. Prominent among these is the best method of returning the empty tram, means of quickly and correctly topping off the loads, type of foundation, and power removal of refuse and prevention of accidents.

Early installations were made where empty trams were arranged to be moved to the rear of machine passing over 2 turntables placed just outside of the mill building. This has proven to be not so good as a continuous half circle track connecting the ingoing and outgoing lines around which the empties may be passed without derailment. Loading trams were topped off to the bail circle either by the eye, or against a too rigid form, or one too lightly constructed. It has been found advisable to have a strongly constructed quarter-circle form, pivotally mounted back of the trams, indicating the correct bail outline half-way. This, together with the body of the tram car, produces a full three-quarters of the finished circle for the tie-handlers to load to, and if the ties bind against the form it swings free from the load and does not interfere with its progress from the mill.

Foundations should be provided which do not go far below the ground surface, since many tie-plants are so located that surface-water would enter and cause serious trouble. Sufficient head-room above the foundation and below the base of the machines must be provided for the refuse removal system. Power transmission is best placed on top of the platform on which the machines rest.

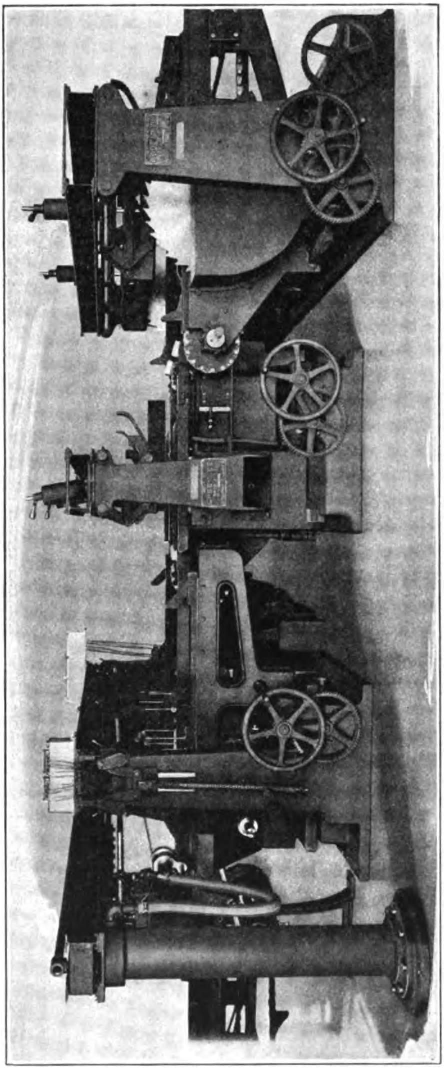
Adzing head-shavings, borings from the bits and dust from the trim-saws are best collected by a rather large-size shavings exhaust fan of special design built to properly handle the extra long shavings produced by the adzing head-knives. This form of fan is demanded, not only because of the length of these shavings, or chips, but also because this cut is made so quickly that the fan gathers them from a machine which produces them evenly.

What to do wlth the shavings after the fan has collected them has always been more or less of a problem. They may be blown through a long discharge-pipe to the power-house, and burned as fuel, but since the tie-machining plant should not be placed too close to the power-house this is hardly an acceptable solution, although it has been successfully operated. Probably the best method is to provide an old box-car which may be switched to a point near the machine, the shavings blown directly into it, and when filled have it switched to the power-plant, emptied, and returned.

The tie ends produced by the trim-saws are best collected by a double endless-chain conveyor, placed in the pit beneath the machine, and delivered to a second oblique conveyor, arranged to elevate them to a large hopper, where they may be accumulated, and from where they can be removed through a swinging trap-door by a wagon, or car, and used for fuel.

The adzing and boring machine line with which your Committee is familiar was started in 1908, and has progressed steadily in use and mechanical development, from that time until the present, except during the period in which this country's industry was checked by the world war, and the number of plants put into operation prior to 1916 would indicate that the necessity of machining cross-ties was being quite generally accepted, and the division between the 2 types of stationary and portable installation is so nearly equal that we are led to believe that both types must have nearly an equal number of arguments in their favor.

Some smaller plants have been made than those used for standard railroad work. The Boston Elevated Railroad has one of



Side View of Tie Adzing, Boring, Trimming and Branding Machine.

these portably mounted in an old street-car. Power is delivered to it by an electric motor, which receives its current from the trolley wire. This machine has been in very successful operation for several years at City Point, Boston. Since there is not sufficient room in the car for the knife grinder, or work benches, these are set up in a shop nearby, and the other auxiliary features are dispensed with.

The Milwaukee Electric Railway Company has a similar outfit mounted on heavy timber skidways, which also support a small house to cover the machine and its driving motor. This plant is used in the tie-yard, and is moved from pile to pile on large wooden rollers.

As an illustration of the extremes in tie sizes that must be provided for, we would cite the fact that the Panama Railroad has one of the standard machines erected in a stationary plant at Colon, Isthmus of Panama. The principal ties are of lignum-vitæ. They are bored for 5 ft. gauge, and are unusually heavy and long.

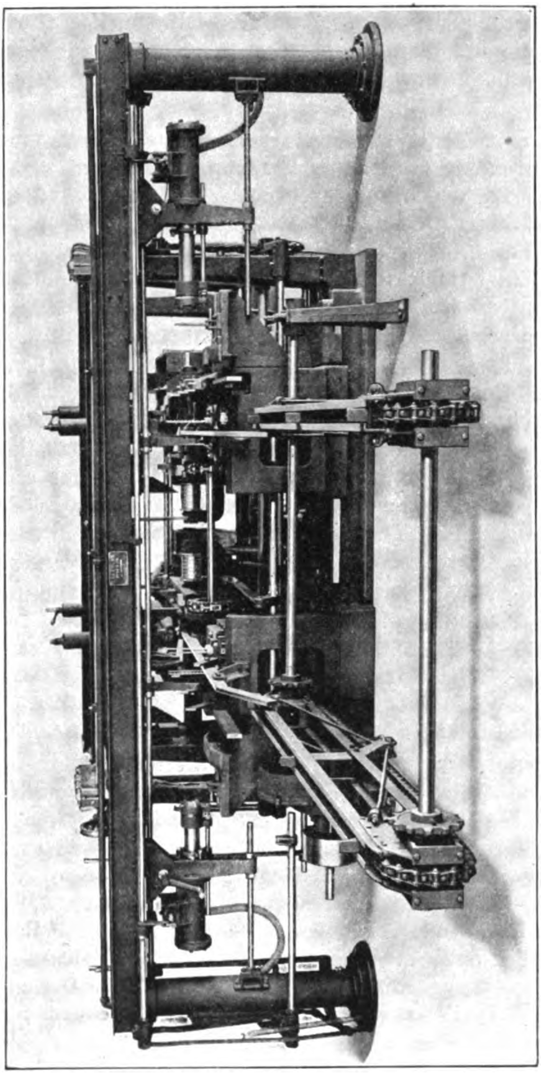
While the Santa Fe have 2 stationary plants at Somerville, Tex., and 1 at Albuquerque, N. M., they are quite favorable toward the portable type for certain classes of work. For several years the standard stationary plant consisted of the trim-saw, the adzing and boring machine, and the branding device, while the portable plant was always built without the trim-saws. The last machine they added to their equipment was necessarily built portable, but they were so strongly in favor of the use of the trim-saws that the manufacturers were called upon to build them a portable plant with this feature included.

A standard steel underframe car of 80,000 lbs. capacity, having a platform 9½ ft. wide, 50 ft. long, with a special body built thereon was used. The trim-saw was placed in one end of the car, the adzing machine, boring machine, and branding device were placed in the center of the car, and a 105 H. P. 6-cylinder gasoline engine power-plant with its fuel, oil, and water-tanks, etc., in the opposite end of the car.

Ties entered the car on in-feed conveyors, passed through the trim-saws, which dropped them onto a special conveyor that automatically passed them endwise to a position in front of the adzing machine where they were automatically picked up by the machine's feeding arrangement, and passed through the adzing, boring and branding operation, and delivered from the car over out-feed conveyors fitted with an accumulating device. Thus the ties enter and leave the car on the same side.

Ties are handled to and from this portable plant in a different manner than any other. The car is switched off on a temporary piece of track to a permanent yard location alongside of a tram-car track. Trains of loaded tram-cars are stopped on this track near

the tie-machine car. A loaded tram-car is placed in front of the in-feed conveyors, and an empty one at the out-feed conveyors.



End View of Tie Adzing, Boring, Trimming and Branding Machine.

As the loaded tram is emptied the other is filled, and the trams then moved along by rope-haul. The load of machined ties pro-

ceeds toward the retorts, the empty tram is moved up to the out-feed conveyors, and another loaded tram of ties cut off from the train and moved up to its position at the in-feed conveyors. In this manner the plant operation is carried on exactly as in the most modern stationary plant, except that it lacks the tram-car unloading device which is now offered as a standard part of the stationary equipment.

This plant includes a second car which forms the tool room. This is a standard box-car, 36 ft. long. It contains a 4-cylinder gasoline engine which furnishes power for the tools in the car, and is also directly connected to a generator which provides current for lighting both cars. The equipment further includes an automatic saw gummer for the trim-saws, an automatic knife-grinder for the adzing head knives, and usual complement of work benches and mechanic's hand-tools and supplies.

The tie-machining car is self-propelling, and among the auxiliary features are the double capstans and rope-haul for moving tram-cars, a shavings exhaust system, which delivers the dust and chips to a temporary house constructed nearby, a small gasoline engine for starting the large one, a water-cooling tower for cooling the circulating water of the power-plants, and the main machines are of the lastest design. This is the most complete portable tie-machining plant thus far erected.

This type of plant is particularly adapted to the needs of railroad companies that wish to purchase machined ties from commercial creosoting plants and own their own equipment for producing them. It has practically all of the advantages of the stationary type when in operation, and can very readily be moved from one yard to another as the company changes its contracts.

In the selection of stationary tie-machining plant equipment it is best to install, or at least provide for the entire outfit in most cases. The mechanical details are such that any part may be omitted and added later without change in the general installation, except that where machines are left out, filling conveyors must be temporarily installed in their space. The auxiliary equipment is practically the same, regardless of whether the complete 4-unit type is used or not. Compressed air must be furnished for operating the branding machine, either from the main power-house, or from a small single-stage compressor, having a capacity of about 25 ft. per minute at 80 lbs. pressure.

The mill building is 1 story high, 14 ft. to the plate with gable roof. It is 66 ft. 6 ins. long by 36 ft. 6 in. wide. A shed, roofed lean-to at one side, forms the tool-room. The tram-track enters one side of the building near one end, passes through the building, returns on the rear side in semi-circular form, and again passes through the building near the opposite end, and this loop forms the incoming and outgoing tram-car tracks.

The building should be placed at least 300 ft. from the main tracks that its tracks be unobstructed for sufficient length to provide storage for 2 complete trains of trams. From the point where the ingoing track enters the mill building and on, it should have a descent of 1½% down-grade that the trams may be easily moved through the mill around the return, and from the mill after reloading.

The general machine foundation, placed a little beyond the center of the building, is a concrete floor with its top surface practically flush with the surrounding ground level. Concrete walls and posts about 5 ft. high carry from this foundation wood beams that support a timber floor that the machines rest on. The floor is of 4 in. plank to which the machines are bolted to keep them in place, but the actual weight of the machinery is carried by the timbers and concrete below.

In front of the machines, and over the incoming track is erected the tie tram-car unloading device. This consists of a worm-gear drive double hoist with direct-connected electric motor. Double chains from the drums hang downward to an equalizing bar from which are suspended additional double chains that connect with long steel links that rest in slots in the floor and returning upward connect at their top ends with heavy cast iron abutments even in height with the top of the tram-car.

As the loaded trams enter the mill they pass through the loop formed by the chains and links, and when the unloading device is started the chains wind up, lifting the load of ties from the trams and rolling them over the abutments, deposit them on the skidways in front of the machines.

The motor for this hoist should be of special type, arranged for elevator service, and to run in both directions. If electric current is not available this device may be efficiently installed and operated with belt-drive from the main-line shaft. Two sections of railroad rail are suspended from overhead about midway of the skid length to prevent the ties from falling as far as the machine conveyors.

In-feed conveyors, approximately 8 ft. long, are provided for delivering ties from the skidways to the machines. The ties are placed on these by 2 laborers who must see that they are the proper side up and in correct location against an end stop. From this point they pass automatically through the machines.

The trim-saws are placed first in the machines train. Most ties, and particularly those of yellow pine, should be trimmed for inspection of their internal state of preservation. Ties having S-irons in their ends cannot be trimmed, nor passed through the machine, when the saws are in running position. The occasional ironed tie can be removed by the laborers in front of the machine, but where the saws are used, care should be taken that ironed ties be selected out and a quantity of them run at one time with the saws moved back from their cutting position.

The adzing machine is placed second in train, and must be provided with modern equalizing cradles that automatically raise and lower the ties for adzing to a depth proportioned to their crookedness, thus cutting away sufficient timber to give good plate-bearing without going so deep that it will really weaken any of the ties.

The boring machine is placed next in train, and should be equipped with at least 8 bit-spindles. When but 4 holes are required for spikes it has been found advantageous to bore additional holes with the remaining spindles for later use in re-spiking, and also for additional penetration of creosote.

The branding machine is placed last in the train. This consists of double pneumatic cylinders, one at each end of the tie, whose pistons carry dies on their forward end, arranged to stamp identification characters into the tie, thus branding it with a stamp of ownership and date of treatment, and effectively doing away with the use of dating nails. Since the dies must not strike S-irons, the operator is provided with a control lever for stopping the action of the brander as an ironed tie passes through.

Out-feed conveyors, about 8 ft. long, must be provided for carrying the ties from the machines to the outgoing tram. These should be equipped with an accumulating device for collecting ties and permitting the exchange of tram-cars without stopping the operation of the machines. The outgoing conveyors must be hinged at the machine and counterbalanced at their outer end that they may be raised and lowered by laborers, who straighten the ties in the tram, bringing the conveyors down to a low position when the trams are empty and raising them to the easiest working position as the load increases in height.

A pivotally-mounted loading form must be provided to the rear of the outgoing tram-track to indicate the outline of the bales and assist the car-loaders in properly finishing off the load. The shavings exhaust system and refuse removal conveyors are placed beneath the platform that supports the machines. The principal countershafting and belting for driving the machines are located on top of the main platform. If electrical current is available the following motors should be supplied: For the main machine, 75 H. P.; for the fan, 15 H. P.; for the unloading device, 7½ H. P., and for the tool-room 3 H. P. If the trim-saws are omitted, the 75 H. P. may be reduced to 50 H. P.

The tool-room must be equipped with an automatic adzing knife-grinder, an automatic saw-gummer, 2 work-benches, a set of mechanic's hand tools and vises, and the necessary jigs and material for the general plant maintenance.

We are now coming to a time when the installation of tie perforating, or incising machines, in connection with tie adzing and boring equipment will be a matter of real moment. Mechanically, this will cause some complication, but no difficulties that cannot be overcome, and the 2 operations performed at the same time with 1 handling.

The incising machine may be placed in advance of the adzing and boring machine, or behind it, and ties incised either before or after the other machining is done. However, incised ties not only more readily absorb preservative, but if this work is performed when they are green, they do not check badly in seasoning. It would not be right to adze and bore a green tie and allow it to warp in the drying process. The real value of the work performed would be lost, and it is, therefore, obvious that ties should be adzed and bored after seasoning, and just before treatment.

It would be best to run green ties through the incising machine at the saw-mill where they are manufactured or when they are first received in the tie-yard. Pile them for seasoning, and adze and bore them on their way from the piles to the treating cylinders. This would demand practically separate plants for the 2 operations, and also cause the ties to be handled twice. Whether the results obtained would justify the extra expense is a matter that must be decided by local conditions.

It is believed best that the ties be seasoned, if the operations are to be performed at the same time. Passing incised ties through the adzing and boring machine would cause no complication whatever, while passing adzed and bored ties through the incising machine would cause the top incising roll to ride over the edges formd by the adzing heads, thus causing extra strains on its mechanism, and the incising teeth would to a certain extent injure the freshly adzed true plate surface. Therefore, it is recommended that incising be performed in advance of boring and adzing.

Ties must pass through the incising machine endwise, and the adzing and boring machine sidewise. It is, therefore, best to install the tie-unloading device, the skidways and the incising machine to one side of the boring and adzing machine. In operation, ties should be dumped on the skidways, as in the present tie adzing and boring plants, from the skidways they would be placed by hand on the incising machine feed-rolls. After passing through the incising machine endwise, they would be picked up by the boring and adzing machine's conveyors, and fed sidewise through these machines in the usual manner. The transfer from the rolls of the incising machine to the conveyors of the boring and adzing machine may be accomplished automatically, or by hand.

D. W. EDWARDS, *Chairman*,
J. H. CURRY,
R. H. MOORE,
J. M. WEBER.

THE PRESIDENT: While the room is still dark we would like to call on Mr. Wheeler. I believe Mr. Wheeler has some slides.

MR. C. L. WHEELER: I gave my slides to Mr. Edwards. The only thing that I might add aside from the description of the machine would be to relate our experience in perforating the first 60,000 ties. I noticed there was considerable applause this afternoon when someone remarked about the interest they wished the Association would take in progressive steps and as this incising machine is considered a progressive operation the Association would probably be interested in a brief report upon the perforating, or incising, of the first 60,000 ties at our plant.

Last fall we installed in our yard a machine of the type just shown on the screen. In speaking of the manner in which it was set up I will discuss it in the manner and as we thought it best adapted to our yard and conditions, and not as it would probably be set up in an ideal yard.

We placed the machine between 2 convergent tracks where we could readily feed to it ties from flat-cars and have the out-feed convey them again onto flat-cars. The elevation of the in-feed was about 3½ ft. above the level of the flat-car. One would probably use a different elevation than we used if they were going to load directly into tram-cars. The machine was placed on a platform with emergency space for about 500 ties provided for so that we could keep the machine running during periods when we were switching out or replacing loads or empty cars. We could use this space as we had a locomotive crane which could readily set over or forward sling load lots. This operation proved to be an economical operation as it kept the machine running.

In incising the first 60,000 ties we observed the following facts: The massive construction of the machine, which is often criticised upon first inspection, seems to be justified by its stability when called upon to undergo unnatural strains. Such strains might develop when an inspector fails to throw out 1 in. to 1½ ins. oversize tie. Of course, oversize is not considered a defect, but when a tie of this type passes the corrugated feed-roll, and strikes the spring tension roll, or incising cylinders, there is a terrific strain on the machine. The machine takes care of such emergencies nicely.

The specifications with the machine call for a capacity of 72 lineal feet per minute. We have run ties through the machine at this speed. However, we were unable to operate it steadily at that rate, for the reason that most of the ties which we have been running were inspected as they left the cars to be placed in the feed-rolls. These ties were brought to the yard from mills without previous inspection. Often we had to turn a tie over, or move it to one side. Of course, under these conditions the machine was not running to capacity. We have, however, been running the machine at a rate of better than 6 ties per minute.

To improve the feeding to a maximum efficiency the plan suggested and portrayed with slides by Mr. Edwards should be followed, or if one were in the position to feed them from water-storage where ties could be readily placed on a long conveyor. The elimination of inspection at the time of feeding to the machine is essential, if possible.

The 15 H. P. motor described by Mr. Edwards has sufficient power to take care of the machine at all times.

To operate the machine, under the conditions we had at St. Helens, at the rate of 7 ties per minute we used 4 men. We had to use an additional man in operating at the rate of 9 ties per minute. If one were feeding the ties into retort-cars, and had some auxilliary feeding, such as heretofore suggested, the machine would be practically automatic, except for the labor of 2 men.

No one part of the machine seems to be out of proportion with the balance of the machine. There have been several minor adjustments, such as the changing of springs and tensions thereon, in order to properly transfer power and get even penetration with the teeth.

As to the cost of operation, which I presume is one of the most important items, we are running ties through the machine at a cost of 1½ cents each. Of course, the cost varies in proportion with the number of items which are listed as perforating, or incising, costs. There would be a variation in the cost when loading ties into retort-cars onto flat-cars for forwarding to seasoning yard, or in placing them in box-cars for shipment. The manner in which ties arrive at the machine also affects our cost. To place ties in the seasoning yard, forward to and feed through the incising machine, later placing in storage, or in cars for shipment, it costs between 3 cents and 3½ cents each.

Of the 60,000 ties we have fed through the machine, one-half were green and the other half were seasoned, and we find that the seasoned ties seem to perforate just as easily, if not more easily, than the green ties. If there are any questions about the operation of the machine I would be glad to try to answer them.

MR. J. A. JOHNSON: I would like to ask the gentleman, from his knowledge, if he has experienced trouble in using previously bored ties in old track that may be out of line, and if so, how do you overcome that?

MR. C. L. WHEELER: We do not operate the boring machine, are just operating the perforating machine.

MR. D. W. EDWARDS: The question is how to use ties of standard gauge in track which has widened in use. It is, of course, obvious that it is necessary to bring the track back to gauge. However, whether you actually do bring the track back to gauge or not, even if that were entirely lost sight of, the boring operation has more than paid, due to the penetration of the creosote at that point made possible by having the tie bored.

In that connection I will say that machines are made with any number of spindles that are required for boring any number of holes in each end of the tie, usually 4 holes in each end, or 8 holes. If you are only using 2 holes it pays to bore 4 to get the penetration of the creosote.

MR. F. N. GRAHAM: All this discussion about perforating refers to cross-ties. Has not some consideration been given to other material, such as bridge stringers and caps?

MR. D. W. EDWARDS: In designing the incising machine the question came up as to what would have to be provided for and various sizes of timber ranging all the way from 3 by 6 to 14 by 20 were suggested. It will be absolutely impossible to put a commercially successful machine on the market that would take care of all that range. Therefore, it was decided to first bring out a machine made for ties and this machine has a range of from 3 ins. to 6 ins. by 10 ins. to 14 ins., and will take care of anything within that dimension, whether it be ties, or what not. My personal view is that we are bound to have some weakenings, due to incising, and I doubt very much whether bridge engineers are going to let us incise their timber.

MR. F. N. GRAHAM: That is just exactly the point I wanted to get at.

MR. D. W. EDWARDS: In connection with the question of incising, or perforating, ties there is a lot of discussion as to how frequent an incision should be made, just how they should be spread, just what form they should be. That, I think, must be worked out entirely from experience. The machine illustrated is designed so that any spacing crosswise of the tie may be taken care of. The tie shown is spaced 1¼ inches. If you want to increase that, or decrease it, it is a very simple matter. Lengthwise of the tie they occur every 2 inches. There is no adjustment that way, but it can be made 4 ins. by taking out every other row of teeth.

There are a great many different ideas as to the form of tooth, and whether that tooth should separate the grain. Whatever is practical we will have to work out. The question is whether we want to use a spade form of tooth that separates the grain, or a chisel type that actually severs it. The tooth itself is so designed that it will not cost a great deal to put an entirely new set into the machine. It takes about 1,000 teeth to fill a machine once.

THE PRESIDENT: Is there any further discussion?

MR. C. E. GOSLINE: I should still like to know how much quicker the perforated tie can be treated than a tie that has not been perforated.

MR. R. E. DEMUTH: Mr. President, the air-dried perforated fir tie samples exhibited were creosoted in about 12 hours, which is also the period of time required for creosoting non-perforated fir ties. The idea in perforating fir ties is to secure an uniform distribution and penetration of preservative, consequently there is no difference in the time of treatment.

MR. H. E. HORROCKS: I just wanted to tell you our experience about 5 years ago. As far as this question of cross-cutting fibers is concerned, it is a serious mistake. I do not think there is any necessity for it, and in the work we were engaged in 5 years ago we perforated on various spacings; we did not have in any instance a cross-cut fiber, and we obtained in every instance penetration equal to these samples shown you.

MR. GEO. M. HUNT: Mr. Horrocks presents one side and I should like to present the other side of the subject. In my opinion you can only get penetration in Douglas fir and many other species by severing fibers. We all know that you get very little side penetration in a check in Douglas fir. There are no fibers severed.

You get good penetration in the end of a tie, that is, through the fibers which are severed. Now, I believe that if a tool could be designed which would make a hole in a fir tie without severing any fibers it would do you very little good. These tools which apparently do not sever fibers do really sever enough to give you the penetration, and I do not believe it is possible to get penetration like that without cutting fibers, and a lot of them.

THE PRESIDENT: If there is nothing further we will adjourn until 10 o'clock tomorrow morning.

THURSDAY MORNING SESSION

January 27, 1921

THE PRESIDENT: The meeting will please come to order. The Chairman has been instructed to appoint a San Francisco Bay Steering Committee to act as a nucleus for next year. The Committee is as follows: F. D. Mattos, R. O. West, C. A. Kofoid, W. C. Ball, C. E. Cortes, A. A. Brown, L. D. Jurs, C. L. Hill (Chairman).

The first paper on the program is the "Use of Creosoted-Wood Conduit on Pacific Coast," by Mr. Judson and Mr. Wismer.

USE OF CREOSOTED-WOOD CONDUIT ON PACIFIC COAST.

By C. H. Judson and E. Wismer.

The adoption of creosoted wood for underground conduit by the low-tension wire companies of the Pacific Coast was the result of recommendations made in 1906 by our consulting engineers of the General Staff of the American Telephone and Telegraph Company that it could safely be employed as an equivalent to the best material then known—vitrified clay.

The underground avenues in which are laid the lead-sheathed cables are perhaps the portion of the telephone plant that is least likely to be changed or supplanted because of changes in the art. Neither do municipal orders interfere with such construction, except in the cases of changes of street grades which cases are exceedingly rare. So it may be assumed that it is extremely desirable to construct these subways of a material that is, so far as possible, imperishable. Long life is what is sought for, and the longer the life and the lower the annual charges, the more nearly ideal is the construction.

Prior to the adoption of creosoted wood for conduit on the Pacific Coast, the only enduring materials which had been installed were vitrified clay and concrete. Vitrified clay was, and still is, used very largely, and from the standpoint of freedom from decay is ideal, while the cost has not been excessive. Concrete has usually proved to be too expensive, and has been little used. With a view to obtaining a material approaching clay in endurance and more readily obtainable, creosoted wood has been recommended and some experimental installations made. Later as it was found that the proper treatment of the wood could be obtained, it was adopted as standard conduit material, and is now to be found in the subway systems in practically every city on the coast.

Bulletin No. 14 issued by the United States Department of Agriculture makes this statement: "Timber penetrated by creosote oil will never rot."

Not only will it never rot, but it appears to be immune from attacks of insects, birds, rodents, and all the lower forms of animal organisms and fungi.

In the light of this information it is easily deducible that a properly constructed subway composed of creosoted-wood duct may be expected, barring mechanical disturbances, to endure for a long period of time. It seems highly probable that, as these facts become better known, and if it remains possible to procure wood conduit at reasonable prices, it is going to be used more and more for the reception of wires and cables carrying comparatively weak currents as well as for pneumatic tubes. But the creosoting must be properly done, the oil must be right and heated to the right temperature but not so hot as to break the structure of the wood, and the impregnation must be complete.

Obviously, there have been many varieties of wood used for conduit as the work has been performed in various sections of the country. To us here on the Pacific Coast the most adaptable, and at once the most plentiful, wood is fir in its several variations, and its behavior under treatment fully warrants its selection.

Next, after the consideration of life, would seem to be cost. From what has been done it is known that the cost of creosoted-wood conduit in place on the Pacific Coast compares favorably with its only rival, vitrified clay. Comparative figures vary more or less according to the freight, but the average has been entirely satisfactory.

In many respects creosoted-wood conduit possesses advantages over vitrified clay; it is lighter, requires less labor in handling, is not easily damaged in transporting, and there is practically no waste. Creosoted-wood conduit almost never requires any preparation for laying, such as smoothing out the ducts, or smoothing off the ends of the conduit which is so frequently the case with clay. There is no extensive labor involved in the preparation of the protection, inasmuch as it is merely a wooden plank, instead of the concrete encasement or shield required for vitrified clay.

Creosoted-wood conduit can be laid more rapidly than vitrified clay as it is usually in long lengths, is lighter and is not subject to breakage. There is no special treatment required in the jointing of the sections as in some other types of conduit, the ends of the sections being mortised and tenoned and fit so snugly as to effectually exclude sand. Creosoted-wood conduit may be laid by any common laborer of average intelligence, whereas all classes of conduit requiring concrete encasement must be laid by men with considerable experience, if it is to be done properly.

Laying creosoted-wood duct does not require that long sections of trench be kept open for great periods of time, since the laying proceeds so rapidly that the trench may be filled very shortly after it has been excavated, and in sand that would cave after drying it is usually not necessary to shore a shallow trench. This saving of time in installation over other types of duct permits of restoring the street to its former condition, or of repaving in less time, much to the satisfaction of city officials. By reason of the square section, and because it is a single-chamber duct, it lays up in an ideal manner, and can be arranged in any desirable rectangular form. This is highly important, since the presence of foreign structures in the streets frequently requires odd and peculiar arrangement of ducts, and with a multiple duct conduit such an arrangement is not always possible. Inasmuch as the conduit is easily cut with a saw, no difficulty is experienced in laying short sections wherever they are necessary.

Creosoted-wood conduit is very flexible and will withstand considerable movement before the joints open, and it is therefore a very satisfactory type of construction for use in soils that are liable to movement or slipping, as in the case of filled ground or on hillsides. This sort of soil has been frequently encountered in some of the larger cities of the Pacific Coast, and the wood conduit has proven satisfactory in these cases.

Wherever a conduit run must be moved for a short distance, either vertically or horizontally, creosoted wood presents a most desirable form for the replacement of the original conduit. The wood pipes are sawed in half, and the cables laid in the lower half and covered with the top half, the whole being bound together by simple mechanical devices, making as complete an encasement as though whole pipe had been used. While this is also a feature of other types of conduit, because of the square section of the wood conduit, the laying up of the split sections is more easily accomplished than that of a round section. There is no question as to the stability of the structure when creosoted-wood conduit is laid, largely because of its form and the long lengths in which the conduit is laid. In multiple runs, joints are always staggered so that there is no distinctly weak spot anywhere.

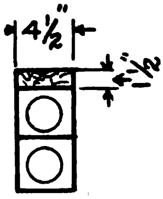
The smooth, oily interior surface of the creosoted-wood conduit assists the installation of large cables. The removal of cables in cases of changes in sizes is easily accomplished, whereas with almost every other form of duct old cables become fixed by the settlement of the lead sheath into any little unevenesses, and are difficult to move.

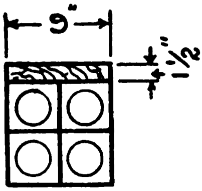
Wherever it becomes necessary to repair conduit runs for any reason whatever, creosoted-wood duct construction is perhaps the most easily handled, for a section can be cut off very quickly and a split section re-installed, sealed with any good sealing preparation, and nailed together, whereas in the case of almost every other type of conduit a good deal of care must be exercised in the removal and replacement of the duct with a consequent increase in the actual amount of labor involved. In the event that a creosoted-wood conduit run containing cables must be moved, it is rarely necessary to remove the conduit, inasmuch as the construction is such that it is easily handled as a unit when desired or as single ducts if preferred.

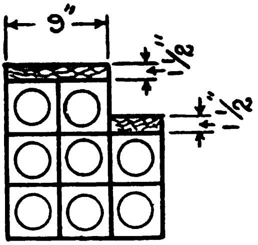
Trench for the installation of creosoted-wood conduit need not be so carefully dug, nor so straight, as required for other types. A narrow trench will permit of the economical installation of creosoted-wood, whereas for the same number of ducts of any other type where concrete must be used more room is necessary for the concrete workmen to operate, and the trench must be very straight in order that the sections join properly.

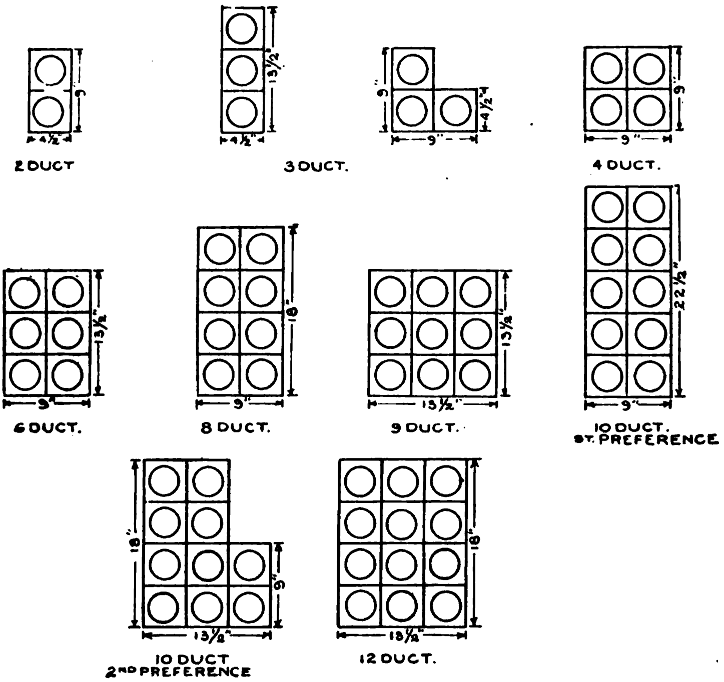
Creosoted-wood ducts ordinarily are laid directly upon the bottom of the trench on 1-inch creosoted-wood plank, which, however, is only used for the purpose of levelling up the structure. The stack of ducts is usually protected on the top by a 1⅛-inch creosoted-wood plank, of a width equal to that of the ducts. There is no further operation necessary after these ducts have been laid and the earth is thrown into the trench immediately after the top plank has been laid.

The following illustrations show ideal cross-sections and the manner of laying creosoted-wood duct.

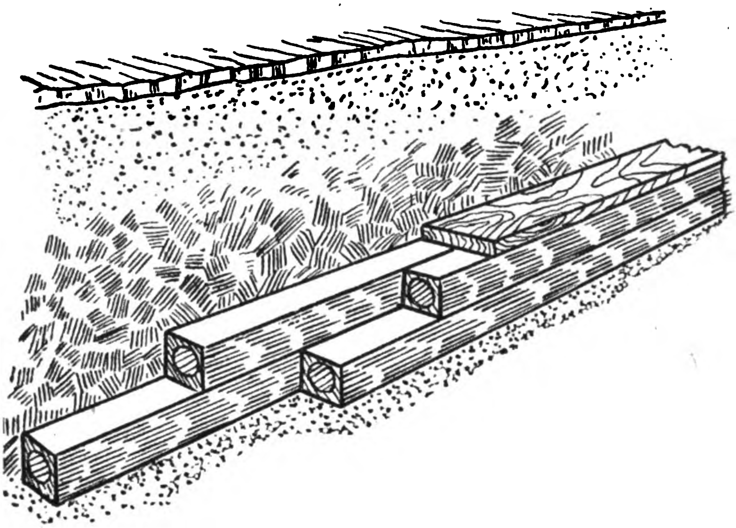








Conduit Cross-Sections—Single Wood Duct.



Laying Creosoted-Wood Ducts.

In 1908 when a large amount of underground construction was installed by the Pacific Telephone and Telegraph Company it was foreseen that the rapidly growing outside plant and consequent heavy overhead leads would tend to place many of the wires in underground cables. Up to this time vitrified clay and paper conduit had been employed for subway construction and owing to the high cost of installing these types of conduit, the recommendations favoring the use of creosoted-wood conduit previously referred to resulted in a very considerable saving.

The first subway constructed by the Pacific Telephone and Telegraph Company with creosoted-wood conduit was at Portland, Oregon, in 1908. As a consequence of the successful treatment of this timber and its ease of installation this company has installed approximately 3,000,000 duct feet since that time, and so far it has given most satisfactory service.

Douglas fir, likewise known as yellow fir, western fir, Washington fir, Oregon or Puget Sound fir or pine, Northwest and West Coast fir, has been used in all of this conduit as it possesses desirable characteristics, and is readily procurable in territory adjacent to established treating plants.

The matter of developing its manufacture was not an easy one, for while Douglas fir piles and heavy timbers were being treated successfully, no experiments had been made in treating this timber in so small a cross-sectional dimension as wood conduit, and the heart wood of Douglas fir does not readily take up the oil.

Wood conduit is made by boring a 3⅛-inch hole in a solid piece of 4⅝-inch square timber in lengths from 2 feet to 8 feet, having a mortise and tenon end, and creosoted.

Before touching upon the more difficult and interesting operation of the treating process we will follow the timber from the time it was received by the mill.

The stock is delivered in the rough about 5 inches square, in random lengths, and is first planed down to 4⅝ inches. It then goes to the cut-off, where it is cut to lengths, and the defective sections removed. It then passes to the borer, where a 2-inch hole is drilled from both ends meeting in the center, after which a 3⅛-inch reamer is passed through the entire length in one operation from one end.

It was found impracticable to drill the 3⅛-inch hole in one operation as the alignment of the bit could not be controlled, and when bored from both ends the tendency to deflect resulted in leaving an off-set within the bore.

At first a 3-inch hole was bored, but due to shrinkage of the timber during seasoning, the bore was enlarged ⅛-inch to compensate for this loss, as a minimum diameter of 3 inches is desired.

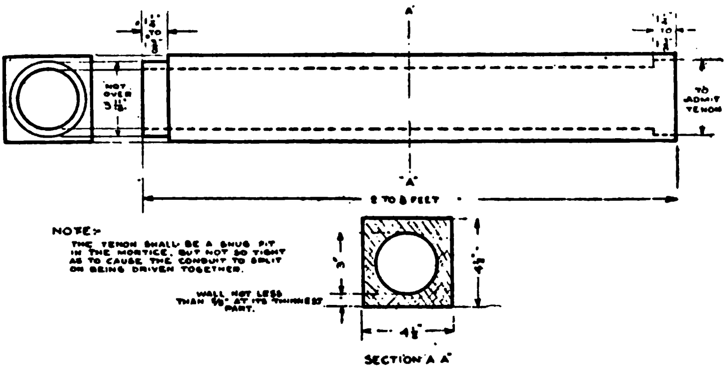
The mortise and tenon ends are now turned, and the conduit is ready for the treating process, and here the real operation begins.

The conduit is inspected before treatment, and great care exercised not to include pieces having knots surrounded with pitch, or pieces having pitch seams extending into the bore, as the heat melts the pitch and causes the knots to fall out, leaving open checks through which foreign matter may enter to clog the conduit after it is installed in the ground.

In the beginning it was necessary to work out many details of the process of manufacture, as the conduit section was much thinner and much more liable to damage by distortion than any form of timber previously treated on the Pacific Coast.

The employes of the treating plant had to familiarize themselves more or less with novel procedures. The pressure and oil gauges and the thermometer had to be carefully and continuously read. Unless great care was taken, the obtaining of a satisfactory product could be defeated by overheating in the seasoning process and by omitting to care for many other details in the handling of the product. In the first treatment nearly 50% of the output became unserviceable, principally from insufficient attention to apparently minor but actually essential details, but final cooperation of all concerned produced satisfactory results with negligible rejects.

Experiments were also made to determine the suitability of hemlock and spruce, but it was found that these timbers have a decided tendency to split, check, and warp, during the treating process.


A
NOT OVER 3 1/8"
TO ADMIT TENON
A
NOTE:-
THE TENON SHALL BE A SNUG FIT IN THE MORTICE, BUT NOT SO TIGHT AS TO CAUSE THE CONDUIT TO SPLIT ON BEING DRIVEN TOGETHER.
WALL NOT LESS THAN 1/2" AT ITS THINNEST PART.
4 1/2"
SECTION A A

Design and Size of Creosoted-Wood Conduit.

While Douglas fir possesses the requisite qualities for underground conduit, it is not durable in contact with the soil, and consequently necessitates a preservative treatment. To insure a long life it was determined that the thinnest part of the wall should be completely impregnated with dead oil of coal tar or coal-tar creosote and experiments indicated such a penetration would require not less than 15 pounds of oil per cubic foot of timber. Creosote was selected for the preservative agent as its principal point of superiority over other antiseptics lies in its insolubility in water, and once it is injected into the timber it will not leach out.

It has been found that green lumber behaves better than seasoned lumber during the processes of mechanical preparation which have been described above. In consequence of this preference for green lumber, the duct as it comes from the shaping machines contains considerable moisture which must be removed, either before it is placed in the cylinder to be treated with preservative, or in the course of the treating process after it has been placed in the cylinder. Climatic conditions and available storage facilities preclude air seasoning before treatment, and seasoning by kiln drying is more expensive than seasoning during the treating process.

In consequence of these considerations, the treating process selected for fir conduit is an adaptation of the well known boiling process. In this process the conduit is first held in hot creosote until the moisture content has been sufficiently reduced to render it more permeable and better prepared for receiving the preservative. The creosote is then forced into the wood under pressure until an impregnation of 15 lbs. per cubic foot is obtained. As will be seen from the details below, a full-cell treatment is sought and obtained in the case of fir conduit.

The salient features of the treating process arrived at will now be described.

SEASONING PROCESS.—The timber is immersed in dead oil of coal tar, and kept covered during the entire period under at least 4 inches of oil. The oil on admittance to the cylinder should be at a temperature of from 155° F. to 186° F., then quickly raised to 203° F. and held at between 203° F. to 208° F. during the remainder of the seasoning process.

The length of seasoning and temperature of oil are regulated by the condition of the timber. Seasoning should be continued until such time as the amount of condensation per cubic foot of timber indicates that the interior of the timber is dry. This condition is practically reached when the condenser yield drops to about 0.11 lb. per cubic foot per hour.

Many experiments were made to establish the correct temperature to which the oil should be heated. If too hot the effect on the timber was that of burning, indicated by a charred appearance, besides causing the duct to warp and check. The latter condition would also result if the temperature was raised too suddenly.

FILLING PROCESS.—When the seasoning process has been completed, all discharge pipes from the treating cylinder are closed and additional oil forced in under pressure, which is gradually increased until the proper quantity has been taken up by the timber. At the end of 1 hour a pressure of 55 to 110 lbs. is generally reached, and increased to between 120 and 125 lbs. at the end of the treatment. The pressure is regulated by the ability of the timber to take up the oil. The temperature of the oil during this process is reduced to, and held at, about 186° F. to 193° F.

The length of the treatments ranges from 6¼ hours to 3¼ hours for the seasoning process, and from 2 hours to 3 hours for the filling process.

PROTECTION PLANK.—In the installation of creosoted-wood conduit a 1½-inch creosoted Douglas fir plank is laid on top of the duct formation to serve as a protective measure, but as no novel features are encountered in the manufacture of this planking, the treating process need not be discussed, except to note that a 15-lb. treatment was determined upon to make the life of the plank correspond to that of the conduit.

CONCLUSION.—In conclusion it may be said from the well known records showing the long life of properly creosoted timber, it seems reasonable to expect that there will be long and satisfactory service from creosoted-fir conduit as now obtained so far as the deterioration of the wood is concerned.

The foregoing paper limited the experience with Douglas fir conduit to the last 10 years, but it is to be understood that the conduit was just as carefully treated and inspected as the conduit represented by the old samples and, therefore, ought to have just as long and as good a service record as this older creosoted material.

This piece of 1¼ ins. x 4¼ ft. creosoted Douglas fir planking has recently been removed from 42nd Street, Seattle, where it was installed about 10 years ago. It will be seen no decay is noticeable and this will serve to corroborate the above assumption.

MR. E. WISMER: We have no slides showing the manufacturing operations of this product, but have for examination on the display table some samples of new conduit and planking which were taken from a recent shipment to San Francisco. We are also pleased to show some samples of old creosoted conduit, plank and cross-arm, thanks to Mr. Hosford, that had been in service a very long time. You will find the different samples on the table, properly identified, and I will read off their history.

Sample No. 1 was cut from 2¼-in. duct, manufactured by the Wyckoff Company, and laid in Sixth Avenue in New York, in 1887. The subway was removed in 1908 in connection with the construction of the Hudson Tunnel system. The subway had therefore, been in the ground for 21 years. This subway was 24-duct capacity, built 6 ducts wide and 4 ducts high, and protected on all sides with creosoted-wood planking. The top of the subway structure was about 3 ft. below the surface of the street. The surrounding material was ordinary loam, which would readily allow water to reach the ducts. There was no exposure to tide-water. For the first 12 years the street was paved with Belgian blocks, laid on sand. For the last 9 years the pavement was asphalt on concrete. Old duct and plank uncovered in removing the subway were found to be in excellent condition, showing no cases of decay.

Samples Nos. 2 and 3 were removed from Market Street, Philadelphia, in 1908, in connection with the building of the Philadelphia Rapid Transit Subway. The exact date on which the conduit represented by these samples was installed is not known, but they were underground for at least 20 years. The conduit was made from white pine, and was treated with dead oil of coal tar.

At the time the subway was taken up the condition of the conduit was noted to be good, and it was saved for reinstallation. Owing to the small diameter of the bore it was not possible to use it except in the construction of such laterals as would be depended upon not to need full-sized cable. These restrictions on the re-issue of the duct made it possible to procure a considerable number of samples for exhibition purposes.

The sample of creosoted cross-arm came from a creosoted yellow pine cross-arm removed from the Washington-Norfolk Line of the American Telephone and Telegraph Company, in 1916. The arm had been installed in 1897 on pole No. 6226, and had, therefore, been in service about 19 years when removed. When removed the arm was found to be of good quality of timber. Several borings were made at different points of the arm, all of which showed complete penetration by creosote.

This cross-arm was subjected to laboratory analysis to determine the amount of preservative which it has retained after its exposure. It was found to contain 12 lbs. of oil per cubic foot at the time of this analysis, which corresponds to an original content of over 25 lbs. of creosote per cubic foot.

THE PRESIDENT: The paper is now open for discussion.

MR. R. F. HOSFORD: There are a couple of points that might be mentioned to add a little to what has been presented in this paper. First, as to the length of actual experience with treated conduits. That goes back to somewhere around 1882, or 1883, when the first treated conduits were used for carrying underground cables. Telephone experience with these conduits has been practically as long as the experience with underground cables. That time, of course, is illustrated by these old samples on the table when northern white pine, or Norway pine, was a convenient material to obtain and treat. The transfer to the southern pine, now used for making conduits, occurred along in the early part of this century, as the northern white pine and Norway pine became relatively difficult and expensive to get.

Another point on conduit practice is that this type of conduit is especially suited to the use of signaling companies, and not so well suited for use by the electric power companies. Underground cables in power distribution carry a large volume of current and the energy that is set free on a breakdown immediately creates destructive arcs. It is customary practice in that class of work to separate the conduits carrying the cable. This square type has the advantage, because of its construction of laying up compactly, but while there is an advantage from the signalling companies standpoint, it is a disadvantage from the power companies' standpoint so that the use of this conduit has been largely confined to signaling companies. It is used by the telegraph companies for enclosing metal tubes used in the pneumatic distribution of telegrams, as well as for carrying cables.

THE PRESIDENT: If there is no further discussion, gentlemen, we will call on Mr. Hosford, General Chairman of the Sub-Committees on Pressure and Non-Pressure Treatments.

REPORT OF COMMITTEE NO. 5-5-1.—PRESSURE TREATMENTS

To the Members of the American Wood-Preservers' Association:

The line of work assigned to this Committee has not been given to any committee in previous years, and the Committee received only general instructions to work toward the development of standard practices connected with the treatment of poles by pressure processes.

As a preliminary to the development of standard practices, this Committee concluded it to be advisable to study and correlate the results obtained in their field of work up to the present time. It also appeared advisable that arrangements be completed looking toward the establishment of a continuing system of service-records covering the behavior of poles prepared in accordance with each of the several different processes of treatment now in commercial use in this country. It was felt that the establishment of an adequate set of service records would be necessary as a basis for the determination of the comparative values of different processes of treatment by those interested in making a selection among them.

Coupled with these arrangements for service records, the Committee concluded that it would be advisable to compile and publish as complete as possible a description of the groups of poles whose behavior in service was to be studied so that any one desiring poles similar to any lot represented in the service records would have adequate information as to the quality of timber used, methods of preparation, treatment, etc., so as to justify the expectation that he could duplicate in his own work the recorded experience of the past.

Working along these lines the Committee is able this year to report details of preparation and treatment for four groups of treated poles which the General Staff of the American Telephone and Telegraph Company is planning to inspect systematically so that an accurate determination of their service efficiency will be secured. The Committee has been working toward arranging for similar service inspection of records by other concerns and covering poles treated by other processes than those represented by the four groups for which details are reported below. It has not, however, been able to carry this work to a stage where anything definite can be reported.

Washington-Norfolk Line.

General.—This line of the American Telephone and Telegraph Company extends from Washington, D. C., to Norfolk, and was completed in November, 1897. There were placed in this line 9975 yellow pine poles treated under pressure with creosote, divided in respect to length and shape as follows:

Pole	25 Lin. Ft.	30 Lin. Ft.	35 Lin. Ft.	40 Lin. Ft.	45 Lin. Ft.	50 Lin. Ft.	Total
Square	3020	5655	583	268	27	2	9555
Round	4	201	120	40	24	18	407
Hexagonal	----	12	1	---	--	--	13
Total	3024	5868	704	308	51	20	9975

The round poles were made from shortleaf pine. The sawed poles were furnished under the following specifications:

> The timber shall be of sound, straight grain, long-leaved yellow pine, free from large, decayed, or loose knots. The top and butt shall be sound, the pole shall be free from sapwood except on the corners at the larger end for limited height.

Treatment.—The poles were obtained in the Southeastern Atlantic States, and treated at the plant of the Norfolk Creosoting Company with creosote, presumably imported from England. Twenty-eight analyses made of this oil show average results as follows:

Distillates.—

	Per cent.
Loss—water, etc., to 170° C.	1
170° C. to 205° C.	2
205° C. to 210° C.	4
210° C. to 235° C	45
235° C. to 240° C.	7
240° C. to 270° C.	16
270° C. to 316° C.	9
Residue above 316° C.	16
Naphthalene, 205° C. to 235° C.	49
Oil not distilling below 270° C.	25
Specific gravity	1.022
Melting point	36° C.
Boiling point	70° C.

The treatment was carried out under the following specifications:

> SEASONING PROCESS.—If the timber is seasoned and contains little sapwood it shall be subjected to superheated steam for from 6 to 14 hours, depending upon the size of the timber, and as directed by the inspector.
>
> The temperature shall be not less than 220° F. and not over 275° F.
>
> If the timber is wet and contains much sapwood it shall be subjected to superheated steam for from 3 to 6 hours, and then to live steam for from 3 to 8 hours, the duration of its exposure depending upon the size of the timber, and as directed by the inspector. The temperature of the steam shall be not less than 250° F., and not more than 275° F.
>
> EXHAUSTION PROCESS.—The seasoning process having been completed, the steam shall be removed and the creosoting chamber exhausted by a vacuum pump to 26 inches.
>
> During this process the temperature of the cylinder shall be maintained above the boiling point of water corresponding to the vacuum obtained (not less than 125° F.) This process shall be continued until the by-product indicates that the water and sap have been removed from the timber, and as directed by the inspector.
>
> FILLING PROCESS.—The cylinder shall next be filled with the dead oil at a temperature of not less than 120° F. nor more than 250° F., and pressure applied until the requisite amount of oil has been forced into the timber, that is, 12 lbs. per cubic foot.

LOCATION AND RESULTS—This line runs through rolling farm country in the northern section, principally on public right-of-way. The soil in the northern section is a sandy clay loam and mixed with gravel in a few localities. Red clay is encountered in the vicinity of Richmond. In the section between Petersburg and Norfolk the contour is less rolling, becoming more level near the sea.

The line is built principally in well-drained locations adjacent to the Norfolk & Western Railroad, for most of this section. Sand is a prominent constituent of the soil in this part of the line. Woods are more frequently encountered, and the line usually passes through or near the towns on the route.

Results obtained from the poles in this line are described in a paper by F. L. Rhodes and R. F. Hosford, published in the Transactions of the American Institute of Electrical Engineers for the year 1915.

Montgomery-New Orleans Line.

GENERAL.—This line of the American Telephone and Telegraph Company contains between the Alabama River, several miles northeast of the city of Mobile, and New Orleans, 7644 creosoted pine poles. This line was completed in the fall of 1899. The poles were furnished under the following specifications:

> The timber shall be of sound, straight grain, long-leaved yellow pine, free from large, decayed or loose knots. The top and butt shall be sound and cut square.

The 30-foot poles and longer, and approximately 50% of the 25-foot poles, were presumably longleaf pine, while the balance were shortleaf and loblolly. They were obtained from the Gulf States, and the size and number were as follows: 25-foot, 6507; 30-foot, 248; 35-foot, 274; 40-foot, 185; 45-foot, 39; 50-foot, 86; 55-foot, 31; 60-foot, 125; 65-foot, 33; 70-foot, 7; 80-foot, 6; braces, 63; guy stubs, 40.

TREATMENT.—The treatment was carried out at the West Pascagoula Creosote Works, West Pascagoula, Mississippi. The poles, which were to be set in marsh land or water, were treated with 15 lbs. of creosote per cubic foot. Those to be set elsewhere were given a 12-lb. treatment. All poles were treated under the specifications described above for the Washington-Norfolk line.

The creosote used was presumably imported from England. The 38 analyses made of this oil show the following results:

DISTILLATES.—

	Per cent.
Loss—water, etc., to 170° C.	6
170° C. to 205° C.	4
205° C. to 210° C.	4
210° C. to 235° C.	46
235° C. to 240° C.	5
240° C. to 270° C.	13
270° C. to 316° C.	6
Residue above 316° C.	16
Naphthalene, 205° C. to 235° C.	50
Oil not distilling below 270° C.	22
Specific gravity	1.03
Melting point	38° C.
Boiling point	107° C.

LOCATION AND RESULTS.—This line follows the Louisville & Nashville Railroad practically all the way from New Orleans to Hurricane, which is a few miles northeast of Mobile. From New Orleans to Pascagoula the route is along the Gulf Coast, and from Pascagoula to Hurricane it is located at some distance inland.

Poles along the coast are set in flat, dry, sandy soil, while those between Pascagoula and Mobile are located in rolling country in a dry sandy soil which is drained by many small streams. Those set in the eastern part of the line, from Mobile to Hurricane, are located in a low, marshy, muck soil. The line traverses a sparsely populated country.

Results obtained from these poles are described in the paper by Rhodes and Hosford referred to previously.

Birmingham-New Orleans Line.

This line, built by the Cumberland Telephone and Telegraph Company, is now operated by the Long Lines Department of the American Telephone and Telegraph Company. It was constructed in 1899, and contains a little less than 6000 creosoted pine poles located between Lumberton, Miss., and New Orleans, Louisiana.

This line was originally built with round Class C 25-foot poles, and they were obtained from forests tributary to New Orleans.

The poles were treated by the New Orleans Wood-Preserving Company. Creosote, which contained a high percentage of naphthalene, was used. We judge this oil was practically the same as that which was used for the treatment of poles set in the Norfolk-Washington and Montgomery-New Orleans lines, and it is probable that they were treated under specifications similar to those used for these two lines. The poles were given a 15-lb. per cubic foot treatment instead of 12 lbs. used for the two lines previously mentioned.

This line parallels fairly closely the New Orleans & Northeastern Railroad.

Charleston-Montgomery Line.

This line of the American Telephone and Telegraph Company includes a section of creosoted pine poles between Augusta, Ga., and Madison, Georgia. These poles were installed in 1897, and number something over 3000.

Southern yellow pine, round, Class C 25-foot poles were used, and were obtained from Georgia and Florida.

They were treated at the Fernandina Creosote Works, Fernandina, Fla., with English creosote containing a high percentage of naphthalene. We understand the poles were treated by a modified Bethell process, in which live steam was first applied for 8 to 12 hours, then superheated steam for approximately an equal period, followed by the usual vacuum and impregnation process. The poles are reported to have been impregnated with upwards of 15 lbs. of creosote per cubic foot.

NEW WORK

The Committee suggests as problems to be assigned for next year's work:

(1) Continue work of arranging for inspections and service records covering poles treated by processes other than the groups described in this year's report.

(2) Study the relation of the perforation method of preparation to pressure-treated poles.

(3) Prepare standard specifications for treating poles by Full-Cell and Empty-Cell methods.

C. C. FRITZ, *Chairman*
E. E. BOEHNE
R. C. EGGLESTON
W. K. VANDERPOEL
A. H. VORUM
ROGER F. HOSFORD,
General Chairman.

MR. R. F. HOSFORD: I will not attempt to read the details printed for these 4 sets of poles, because a good portion of the record is in tables that are almost impossible to read aloud, and because I think you will get what you want by reading from the report.

On three of the 4 groups of poles, I might note that we found the practice indicated by the records to have called for rather longer periods of steaming than anyone today attempts on the same class of material, and also that the use of superheated steam was called for. As regards another feature, I think it may be of interest to note that while detailed service-records of very recent date are not available at this time on these 4 groups, the results of experience up to 1915 have been published for 2 of them, and the plant-records on the other 2 lots show that the behavior of the poles in these lots was equally as good as in the 2 lots on which more detailed information is available.

The plant-records on all of these 4 lines show the same feature that has been brought out from time to time in connection with the service results from treated ties. That is, the maintenance requirement on these 4 treated lines in the way of putting in new poles has been very light. Practically in every case, except the first one reported on, there is a section in the same line of untreated poles cut from a different timber, and whereas only a few poles per mile have been worked on in these treated sections, in the untreated sections in the course of say 20 years, an amount of work has been done practically equivalent to working on every pole per mile at some time or other.

In regard to recommendation one I think it may be of interest to point out that the 4 sets of poles covered in detail in this year's report cover a range of locations from one in Louisiana and Mississippi, one along the Gulf Coast, one in Central Georgia, and one just south of the Potomac River. We expect that 2 more sets of pressure-treated, full-cell process poles in Texas will be added, so the whole stretch from Texas to Virginia can be covered with service-record cases.

We also are seeeking, although the work has not yet led to anything of very great promise for the immediate future, to locate suitable sections of poles treated by the Lowry process.

THE PRESIDENT: Gentlemen, the report is now open for discussion. If there are no questions to be raised on the question of pressure treatment we will ask Mr. Hosford to continue on non-pressure treatment.

REPORT OF COMMITTEE NO. 5-5-2—NON-PRESSURE TREATMENTS.

To the Members of the American Wood-Preservers' Association:

The instructions to this Committee, based upon the progress made last year were as follows:

(1) Continue steaming experiments to a definite conclusion.

(2) Determine what proportion of the preservative employed is lost during non-pressure treatment, and the extent to which this loss is influenced by the volatility of the oil.

(3) Study the practicability of insuring the desired penetration of oil at the ground line of poles by mechanical perforation preliminary to the treatment.

The Committee was not able to come to definite conclusions upon any of the work assigned to it, but certain experimental work was done and progress made as indicated below.

(1) No work was done upon the effect of steaming upon case-hardening or upon the absorption and penetration of oil.

(2) To obtain information upon the amount of creosote lost during open-tank treatment, two experiments were made at the Page & Hill plant at Minneapolis.

(a) First Experiment.

The first experiment was made by Mr. Burnes of the Page & Hill Co. The tank used in this experiment was one in which poles are given the 15-minute dipping treatment (specifications "AA"). It is a cylindrical tank, 5 feet in diameter and 11 feet high, with a 6-inch flange at the top.

The tank is set about 8 feet in the ground, and is equipped with steam coils to insure a constant temperature of the oil during treatment. In location, the tank is protected from the wind by sheltering buildings and, also, by the 5 feet of tank wall above the surface of the oil.

The oil valves governing the intake and outlet from the tank were carefully cleaned to prevent leakage from the tank after the experiment was started. In order to simplify the experiment, and to avoid resetting the intake valve to prevent leakage, no oil was added after the experiment was started.

PROCEDURE.—Measurements were taken with a graduated steel rod, and the weights figured from the volume and temperatures obtained. An amount of creosote equivalent to 8,400 lbs. was run into the tank, and the temperature raised to 230° F. and held there for 72 hours. The character of the original creosote was as follows: Specific gravity, 1.0769;—distillate up to 200° C., 2%; 205° C. to 210° C., 0.0%; 210° C. to 235° C., 15%; total distillate, 17%. Analysis according to the American Wood-Preservers' Association method.

Measurements were taken at the end of each 24-hour period, and the readings recorded. The losses from evaporation over the three periods when calculated to pounds per square foot of surface exposed, and in per cent of oil involved, are shown in the table below.

24-Hour Period	Lbs. Oil Lost	Lbs. Lost per Sq. Ft. Surface Exp.	Per Cent. Oil Lost
1	256	13.6	3.0
2	195	9.9	2.3
3	115	5.8	1.3

The total number of pounds oil lost over the 72-hour period was 566. Total per cent of oil lost was 6.6.

The character of the oil after the experiment was run as follows: Specific gravity, 1.0861;—distillate up to 200° C., 1.2%; 205° C. to 210° C., 0.3%; 210° C. to 235° C., 12.3%; total distillate, 13.8%.

These losses are probably in excess of what they would be under operating conditions, due to the fact that no treating was done while this experiment was carried on. Had there been poles treated, the loss would have been lessened, since the poles would cut down the area of exposed surface approximately 40% to 50%. There would doubtless be a slight increase in evaporation loss, due to the new oil which would be added to replace oil injected into the poles, but the decreased amount of exposed area would cover this increased loss and still show considerable decrease in the total amount of evaporation loss.

In comparison with the data submitted by Mr. Bateman last year, it will be noted that the losses in the above experiment were much greater. This was no doubt due, in large measure, to the higher temperature, 230° F., used by Mr. Burnes as compared to the 195° F. used by Mr. Bateman.

The temperature for the first 24-hour period averaged 26° above zero, and the evaporation showed heaviest on that day, which should have been expected from the character of the oil at that time. A comparatively small amount of naphthalene formed about the tank during the first period.

In the second period the average temperature was 8° below zero, and there was a much heavier coating of naphthalene formed, although there was a marked decrease in the amount of oil evaporated.

During the third 24-hour period the average temperature was 11° below zero, and a coating of naphthalene 2 inches thick had settled on the inside of the tank. A dense white cloud of creosote fumes hung over the tank all day, and naphthalene was continually falling back into the oil from the sides of the tank. It seems plausible that the intense cold condensing the creosote vapors before they could escape from the tank might easily be a factor in the low amount of oil evaporated during the third 24 hours, especially when the comparatively slight differences in the character of the oil before and after the experiment are noted.

(b) Second Experiment.

The second experiment was made by Mr. Burnes and Mr. Sporley. This consisted in making a number of 4-hour hot-bath treatments from the same tank of oil *, taking samples from the original oil and after each treatment, and noting the changes which took place in the character of the oil.

Approximately 5000 gallons of oil were placed in a receiving tank, and throughout the series of treatments was kept separate from all other oils.

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*The regular cold-bath treatment was made on these poles from another tank of oil, hence does not figure in these experiments.

The treating tank was oval in shape, having maximum dimensions of 7 feet by 15⅛ feet, and a depth of 11 feet. It was completely filled with poles for each run, requiring approximately two-thirds of a carload to the charge.

The treatment, which entered into this experiment, consisted of a 4-hour hot bath at 230° F., after which the oil was pumped back into the receiving tank and allowed to mix with the oil in the tank. A sample was then drawn from the receiving tank at a point of 3 feet from the bottom. In this way six treatments were made consuming about 4000 gallons of the original 5000 gallons.

At the conclusion of the work the 7 samples were analyzed by Mr. Burnes and Mr. Sporley, using the standard A. W.-P. A. 8-ounce flask, and the American Telephone and Telegraph Company's method of analysis. (Their specifications No. 3744.)

The results of the analyses are given in the accompanying table. It will be noted that there was no marked progressive change in the character of the oil. The water content was low in the beginning, and it disappeared entirely after the first treatment.

The irregular differences between the various analyses may be due to the method of taking samples. The method used was necessary, because the plant was not equipped for taking samples otherwise; but it is felt by the Committee that more uniform results might have been obtained if the oil could have been more thoroughly mixed before sampling, and if a drip or thief sample could have been taken instead of the tap sample.

(c) Perforating Process.

With regard to the perforating process, the Committee is able to report that substantial progress is being made by the Western Cedar Pole Preservers at their plant at Sand Point, Idaho. At this plant a machine has been erected for perforating poles in commercial quantities, and it has been in operation since about June 1, 1920.

The perforating is accomplished by chisel-pointed punches in the ends of heavy iron bars. These bars are raised by cams and allowed to fall, driving the punches into the wood by the weight of the bars. The distance through which the punches fall is regulated by an adjustable carriage upon which the pole rests, but is usually 2 to 3 inches.

RESULTS OF ANALYSES HEATING PERIODS.

Sample No.	When Taken	Specific Gravity	Tar Acids	Sulphonation Residues	Benzol Insoluble	Water Content	Distillation up to									
							170° C.	205° C.	210° C.	235° C.	245° C.	270° C.	300° C.	315° C.	360° C.	Residue
			%	%	%	%	%	%	%	%	%	%	%	%	%	%
1	From car	1.121	4.2	0.80	0.30	0.25	0.61	1.10	1.27	2.66	3.53	9.49	17.82	43.44	49.72	50.01
2	After 1st run.	1.122	3.6	1.15	0.17	0.00	0.39	0.69	0.79	1.32	2.54	11.84	20.63	26.13	47.62	52.13
3	After 2d run.	1.125	3.6	1.80	1.80	0.00	0.17	0.57	0.57	2.39	3.00	11.28	21.10	26.98	47.04	52.40
4	After 3d run.	1.121	5.2	1.40	0.24	0.00	0.07	0.56	0.81	2.46	3.48	14.00	25.77	34 30	55.37	44.36
5	After 4th run.	1.125	4.2	1.40	0.24	0.00	0.41	1.04	1.20	3.60	8.00	15.33	29.63	33.43	56.54	42.85
6	After 5th run.	1.122	5.2	1.40	1.05	0.00	0.07	0.50	0.55	2.93	5.72	17 45	27.70	33.28	52.62	47.11
7	After 6th run.	1.121	3.4	1.60	0.32	0.00	0.08	0.55	0.65	3.51	6.54	17.50	23.39	34.18	56.00	43.63

The bars are arranged in a vertical line along the pole, each bar operating independently, but all are released at the same time. This perforates a line of holes lengthwise of the pole. The pole is then automatically turned a specific distance, and another line of holes perforated. In this way the entire surface of the poles for a distance of 1½ feet above and below the ground line is perforated. The holes are so spaced that the oil is required to travel a distance of 2½ inches vertically, and not more than 1/16 inch circumferentially, in order to obtain complete penetration.

The machine is not yet mechanically perfect in some details, and the operators plan to improve its construction. It is stated, however, that as now operated the machine permits of practically complete penetration of oil to the depth of the perforations. It is also stated that in some cases this penetration is not secured during treatment, but the continued movement of the oil in the wood after treatment is said ultimately to treat all the wood between the holes.

As the poles arrive at the treating plant there is considerable difference in the ease with which they can be treated. The same spacing of holes would, therefore, not be best for all classes of poles. Whether a spacing should be used which will give penetration in the most difficult poles, and therefore for all poles, or whether a different spacing should be used for different classes of poles is a matter which needs further consideration.

RECOMMENDATIONS.

The Committee is not possessed of sufficient information to draw any conclusions or make any recommendations with regard to this machine or these statements. It is greatly impressed with the possibilities of the perforating process, however, and recommends that the subject be given continuous study during subsequent years until definite conclusions can be reached. Some questions which must be answered, and data which should be made available, are listed below:

(1) Make computations of the probable loss of strength, due to different spacing and depth of perforations, and different sized holes.

(2) Make strength tests to see how the actual strength losses compare with the computed losses.

(3) Determine the effect of the perforations upon checking.

(4) How much does oil spread from the perforations after treatment? Is there an appreciable differ-

ence between the completeness of penetration immediately after treatment, and say 4 weeks after treatment?

(5) When perforating is used is it necessary to shave off the inner bark?

(6) What is the most efficient size and shape of punch to give the desired penetration with the least reduction in pole strength?

(7) To what depth should the perforations be made?

(8) Study the relation between the amount of oil absorbed and the penetration obtained.

It is recommended that work be done by the Committee on questions 1 to 5, inclusive, during the coming year.

L. L. HILL, *Chairman*
W. M. CARPENTER
L. A. FURLONG
G. M. HUNT
C. M. SPORLEY
ROGER F. HOSFORD,
General Chairman.

THE PRESIDENT: Gentlemen, the report of this Committee is now open for discussion. If there is no objection we will accept the report as information.

We will ask Mr. Hunt to read for us Mr. Bateman's paper on "A Theory on the Mechanism of the Protection of Wood by Preservatives, Part II—The Isolation of Barren Oil from Coal-Tar Creosote and a Mathematical Proof of the Existence of a Solubility Partition."

MR. GEO. M. HUNT: This is a continuation of Mr. Bateman's paper of last year, and gives the results of his study since that time on creosote oil and the results of his attempt to get at the bottom of the factors which influence the effectiveness and the value of creosote oil.

Mr. Bateman does not present this paper with the idea of saying that he has thoroughly established the validity of these equations and curves, but he is presenting it in the hope that his ideas will be given careful study, and that he will be able to get during the coming year a discussion which will help him in carrying the work further and in getting at the fundamental facts which affect the value of creosote oil and its uses. [*Applause.*]

A THEORY ON THE MECHANISM OF THE PROTECTION OF WOOD BY PRESERVATIVES.

PART II.

The Isolation of Barren Oil from Coal-Tar Creosote and a Mathematical Proof of the Existence of a Solubility Partition.

By Ernest Bateman.*

Last year there was presented at the convention in Chicago "A Theory on the Mechanism of the Protection of Wood by Preservatives."[1] This theory as applied to creosote presumed that creosote consisted of 2 groups of compounds, 1 of these being sufficiently soluble in water to render the water toxic, the other insoluble and hence non-toxic and that the non-toxic oil acts as a reservoir for the toxic oils and feeds them automatically to the moisture in the wood.

It is the purpose of this paper to present a progress report of the new results obtained since last year. The paper is divided into two distinct parts: First, experimental work of obtaining a non-toxic or "barren" oil from coal-tar creosote; and, second, a mathematical treatment to point out the existence of a solubility partition in data already existing and published for other purposes.

A fairly definite relationship[2] has been shown between the toxicity of coal-tar creosote and the amount of creosote which distills below 270° C., the oils containing the larger proportion of low-boiling oils being more toxic than those containing lesser amounts. It was natural, therefore, in looking for a non-toxic, or barren oil, that those oils having the largest proportion of high-boiling materials should be first attacked. The work at the U. S. Forest Products Laboratory at Madison, Wis., has been confined to high-boiling creosotes.

The first work was on fraction 4, which has been frequently mentioned in connection with various experiments of the laboratory. This fraction was first distilled through a Hempel flask and all the material boiling below 270° C. rejected. This distillate above 270° C., was cooled and freed from solid matter by freezing and pressing. The liquid thus obtained was washed first with caustic soda solution, and then with dilute sulphuric acid to remove as much as possible of the tar acids and tar bases which it contained. It was then boiled for 3 weeks with solutions of acids and akalis, using fresh acid and alkali each day and alternating the treatments until finally the aqueous solutions remained clear and gave no tests for tar acids or tar bases. The oil was then dried and distilled. When this oil was tested for its toxicity against *Fomes annosus* by the standard toxicity test used at the Forest Products Laboratory, 20% of the oil failed to kill the fungus, although there was a slight retardation in its growth. The yield of this oil was rather small, probably due to the excessive amounts of solid hydrocarbons.

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*Chemist in Forest Products, Forest Products Laboratory, Madison, Wis.

[1] Proceedings, American Wood-Preservers' Association, 1920, p. 251.

[2] Wood-Preserving, Vol. III, No. 4, 1916.

High-boiling liquid coal-tar wood-preserving oils were next investigated as a source of barren oil. An ordinary commercial oil was selected, which had the following distillation[3], using an ordinary flask:

	Per cent.
Up to 285° C.	24.7
From 285° C. to 340° C.	28.5
From 340° C. to 410° C.	35.4
Residue above 410° C.	11.4
Total	100.0

A total of 1300 c.c. of oil boiling between 285° C. and 410° C. were obtained. This oil was treated with dilute acids and alkalis, as previously described in fraction 4 and afterwards distilled and tested for its toxicity. A yield of 820 c.c. of bright, clear oil was obtained, amounting to 63% of the original oil, boiling between 285° C. and 410° C., or 40% of the total oil. This "barren" oil failed to kill *Fomes annosus* when used in amounts up to 20%.

Fig. 1 shows a culture of *Fomes annosus* growing on agar-agar, containing 20% of barren oil 2 weeks after inoculation with the fungus. This experiment shows conclusively that there is in coal-tar creosote a non-toxic, or barren oil, and that this barren oil may be present in considerable quantities which supports the theory as given last year[4].

Shackell[5] has shown that in the case of limnoria the effective toxic material is at least dissolved in water. In fact, the methods used in testing the toxicity of materials against both the marine borer and fungi are such as to practically prove that water solubility is a necessary function of a wood preservative. If we accept this water solubility as proven, then there remains only to show that the non-toxic oil acts as a reservoir for the toxic material to make the proof of the theory complete.

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[3] The previous experiment showed that it was somewhat easier to obtain a non-toxic oil if the fraction were cut at 285° C. rather than 270° C.

[4] Proceedings, American Wood-Preservers' Association, 1920, p. 251.

[5] Office report at Forest Products Laboratory, digest published A. W.-P. A., 1916.

The second part of this paper deals with a mathematical treatment of toxicity data collected by Humphrey and Shackell, and attempts to show that a solubility partition[6] exists in certain coal-tar fractions. If there is a solubility partition, then the creosote may under certain conditions act as a reservoir for the toxic materials.

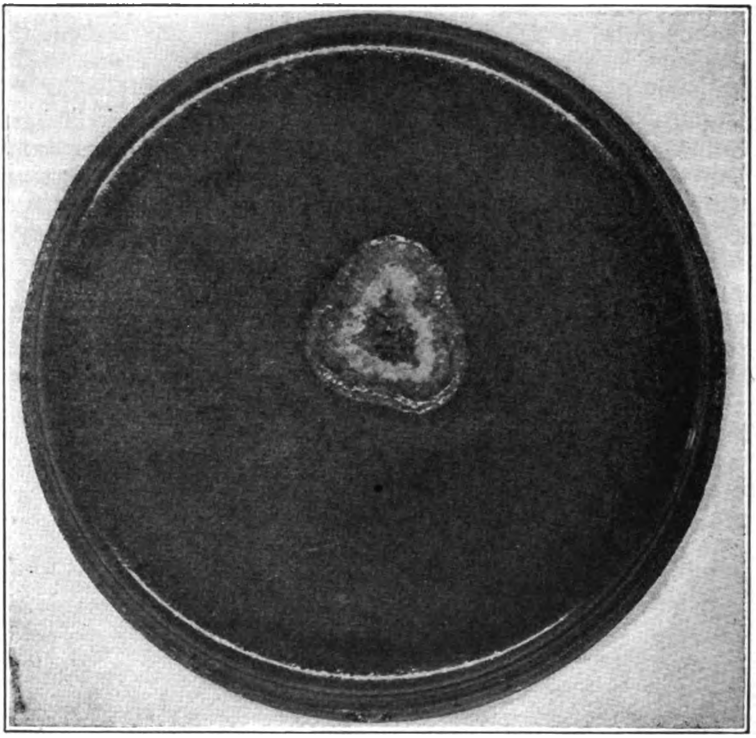

FIG. 1.

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[6] When any material is mutually soluble in 2 other materials which are insoluble in each other, the mutually-soluble material divides itself between the 2 media in a very definite manner, if these 3 materials are mixed together. The manner in which the mutually-soluble material is divided is such that its concentration in 1 medium is in a definite and fixed ratio to its concentration in the other. This ratio is called solubility partition, and is always the same for any 3 materials.

Shackell presented a record of his experiments on limnoria to the American Wood-Preservers' Association in 1916, in which he showed the effect of known quantities of preservatives upon the wood destroyer. As a measure of the effect, he chose the

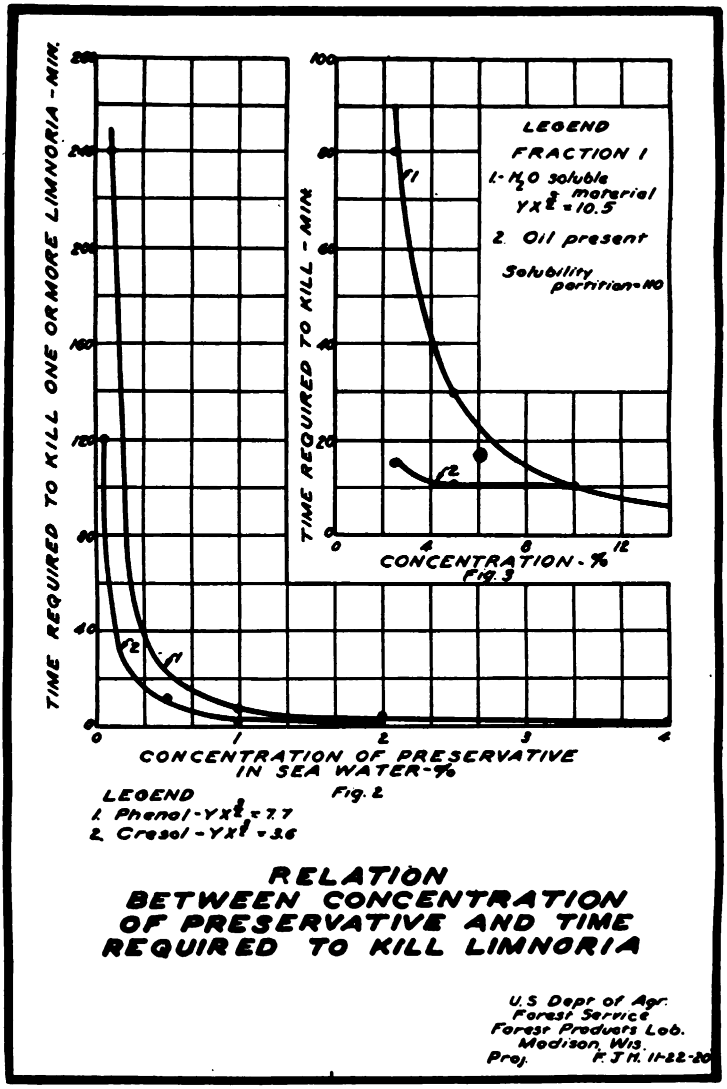


FIG. 2.

length of time required to kill limnoria immersed in sea-water containing the preservative. Curve 1, Fig. 2, shows the time required to kill 1 or more limnoria when immersed in various concentrations of phenol in sea-water. The time required to kill 1 limnoria was chosen, because it was impossible to obtain from the data the time required for all of them, and also because this strength of preservative is the minimum which can be considered as effective, since naturally the weak animals would be killed first.

The equation for this curve is $YX3/2=K$.

Where Y is the time required to kill, X the concentration of the preservative, and K the constant.

The left side of the equation includes the killing time and concentration of preservative. It does not refer to the type of preservative used, but merely says that by varying the concentration, the killing time is varied. The same equation, but with a different value for K, should, therefore, fit all water-soluble preservatives when used against the same organism. Curve 2, Fig. 2, shows the curve for cresol derived from this equation by solving for K at the 1% point. The resulting curve passes through the other experimental points within the limits of experimental error, thereby proving the accuracy of the equation.

Shackell also mixed 10 gms. of fraction 1 and 100 gms. of sea-water, and then tested the toxicity of the water. He then diluted the toxic water with an equal amount of sea-water, and subsequently diluted this to contain only one-fourth of the original toxic material dissolved from the 10 gms. of creosote.

Fig. 3, curve 1, shows the effect of diluting the water-soluble material obtained in 100 gms. of water from 10 gms. of fraction 1. The point plotted at 5% represents the concentration of water-soluble material obtained by diluting the above solution to one-half its volume. The point plotted at 2.5% represents a second dilution of the same material.

The curve was obtained by solving for K in the equation $YX3/2=K$, using the point plotted at 5%. The curve passes through the other 2 experimental points. This shows that the water-soluble-toxic material in fraction 1, when separated from the oil, affects limnoria in the same manner as other water-soluble materials.

Shackell further tested fraction 1 by using 2½ gms., 5 gms., and 10 gms. of creosote suspended in 100 c.c. of sea-water. Curve 2 in Fig. 3, represents the toxicity of fraction 1 when different amounts of oil are used in contact with water.

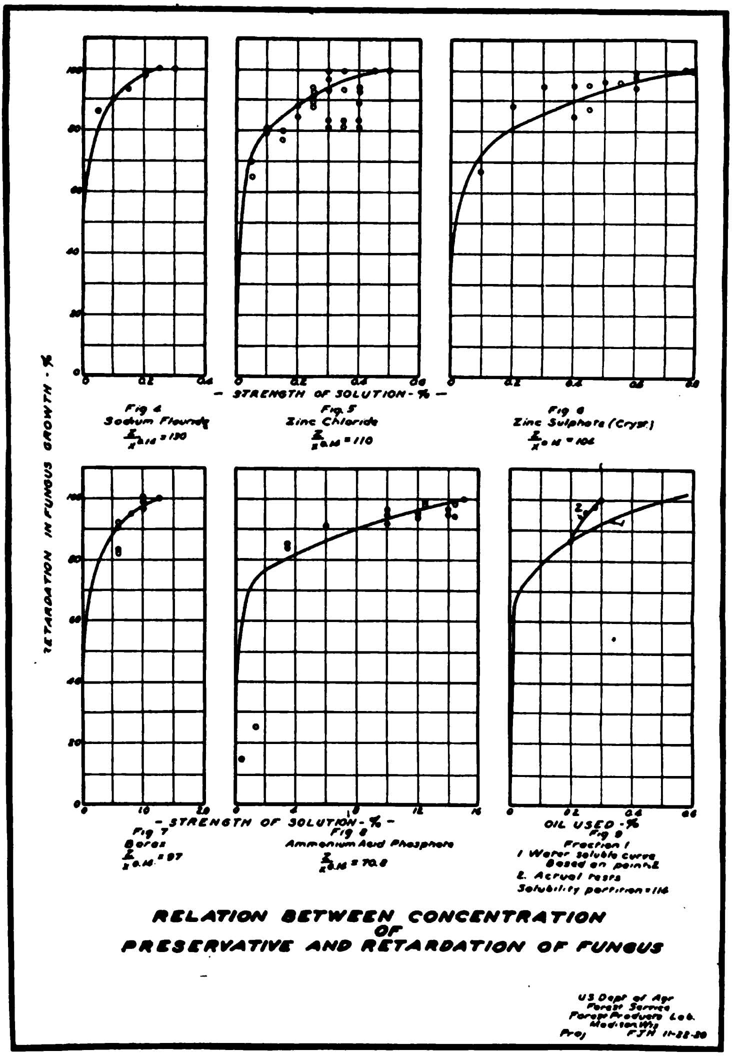

RETARDATION IN FUNGUS GROWTH - %
0
20
40
60
80
100
0
0.2
0.4
0.6
0.8
- STRENGTH OF SOLUTION - % -
Fig 4
Sodium Flouride
$\frac{Z}{X^{0.16}} = 130$
Fig. 5
Zinc Chloride
$\frac{Z}{X^{0.16}} = 110$
Fig 6
Zinc Sulphate (Cryst.)
$\frac{Z}{X^{0.16}} = 106$
0
10
20
4
8
12
16
- STRENGTH OF SOLUTION - % -
Fig 7
Borax
$\frac{Z}{X^{0.16}} = 97$
Fig 8
Ammonium Acid Phosphate
$\frac{Z}{X^{0.16}} = 70.8$
OIL USED - %
Fig 9
Fraction 1
1 Water soluble curve
Based on point 2
2. Actual tests
Solubility partition = 116
1
2
RELATION BETWEEN CONCENTRATION
OF
PRESERVATIVE AND RETARDATION OF FUNGUS
US Dept of Agr
Forest Service
Forest Products Lab.
Madison Wis
Proj FJH 11-22-30

FIG. 3.

If the water dissolved all the material from the creosote, then he should have obtained the same result if he used 10 gms. of creosote and 100 gms. of water, and subsequently diluted the water solution to one-half its strength, as he did by using 5 gms. of creosote and 100 gms. of water. If, however, the toxic material were much more soluble in oil than in water then he should get a stronger aqueous solution, using 5 gms. of creosote than with 10 gms. of creosote, and subsequently diluting to one-half strength.

Let us suppose that the toxic material in some given oil is 100 times more soluble in the oil than it is in water and that we have 1 gm. of toxic material dissolved in 9 gms. of oil. If we put this oil solution in contact with water the toxic material will divide itself between the oil and the water in such a manner that the concentration of the toxic material in oil is 100 times its concentration in water. The amount of toxic materials dissolved in the oil will be the concentration in the oil multiplied by the weight of oil. Similarly, the amount of toxic material in the water will be its concentration in water multiplied by the amount of water. If then we put 1 gm. of toxic material and 9 gms. of oil in contact with 100 gms. of water, the amount dissolved in the 2 media will be in proportion to their weight times their concentration. For oil this will be 9 x 100, and for water 100 x 1; that is, 0.9 gm. of toxic material will stay dissolved in the oil, and 0.1 of a gram will be in the water. The concentration of the toxic material in water will, therefore, be 0.1%.

If, however, only 4.5 gms. of oil were used and 0.5 gm. of toxic material with 100 gms. of water, then the ratio would be for oil 4.5 x 100, and for water 100 x 1. The toxic materials in this case would be divided as follows: 0.41 gm. dissolved in the oil, and 0.09 gm. dissolved in the water. The concentration in the water would, therefore, be 0.09%. In other words, by reducing the amount of oil and toxic material by 50% we have reduced the strength of the water solution by only 10%. If then we find the results obtained by using one-half as much oil different from the results obtained by diluting the water solution to one-half its concentration it proves that some of the toxic materials are held in the oil. Curve 2 in Fig. 3 represents the toxicity of fraction 1 when different amounts of oil are used in contact with water.

From these two sets of data the solubility partition of the toxic material in the toxic oil and water can be calculated if we assume that equal effects on the limnoria are caused by equal concentration of the toxic material in water. Neither the concentration of the toxic material in water nor the amount originally present in creosote need be known for this computation. Calculations based on these hypotheses show that the solubility partition of the toxic oil in the non-toxic oil and in water are as 110 is to 1, that is, the toxic oil is 110 times more soluble in creosote than it is in water.

The data collected by Humphrey on the toxicity against *Fomes annosus* have also been analyzed mathematically. It seems likely that the equation $Z/X0.14=K$ is correct for this fungus, where Z is the percentage retardation in the growth of the fungus caused by the concentration of the preservative. Z is obtained by subtracting the retarded growth as measured in the petri dish, from the normal growth of the fungus, and dividing by the normal growth.

Figs. 4 to 8 show the equations and experimental data of 5 materials which have been tested against this fungus. It is to be noted that the equations differ from each other only in the value of K. The data and the curves fit as well as could be expected, particularly in view of the fact that the data were not collected with the idea of subjecting same to mathematical treatment, but only to give some idea of the toxicity of the preservatives. If then we apply this equation to some point on the toxicity data of fraction 1, we ought to obtain a second pair of curves from which the solubility partition could be calculated.

Fig. 9 shows such a pair of curves. The lower curve is derived by solving for K in the equation $Z/X0.14=K$, using the 0.2 point, which has been checked 6 times with an error of less than 1%. Here again, as in the case of limnoria we find that the curve, which should have held if it were a straight solubility condition, does not hold for oil solutions. The solubility partition calculated from this data is 114, which is not far different from the 110 obtained from Shackell's data. Further proof of this is, of course, necessary before it can be accepted as final, but it is at least a very strong indication of the correctness of the theory put forth last year.

Experiments are now under way to substantiate the calculated data discussed. Should these experiments show and it seems likely that they will, that this is the correct hypothesis it will point out the way in which experiments must be conducted: (1) to foretell the probable life of any wood-preserving oil, be it coal-tar creosote, coal-tar solutions, water-gas tar, or any other oily material; (2) to determine how far we might go in diluting creosote in order that ties may have the same preserved life as their mechanical life; and (3) to fortify creosote against the attacks of marine borers. Experiments of the nature are, however, time-consuming and expensive, and at our present rate it may require a long time for the work to be completed.

THE PRESIDENT: We would be very glad to have anyone discuss this paper.

MR. C. M. TAYLOR: There has been some criticism in this convention as to its being non-technical. I think that we have sort of turned over a new leaf this morning. We have had creosoted conduits shown to us as the best types of creosoted material; we have had Mr. Bateman's paper here on the solubility of creosote oil, which is a rather advanced thought. This is the second time Mr. Bateman has brought this before you, and I trust that there will be considerable discussion on the part of all. This type of oil that Mr. Bateman has developed, as he called it "barren oil," certainly indicates to us that we know very little about creosote oil as yet. As you know, some railroads are now mixing creosote oil with petroleum oil, and they think they are on the right track. By such experiments as these that Mr. Bateman carried on they ought to be able to determine ahead of time just what toxicity conditions they have in their mixed oils. This is in line with the thought that we have not as much creosote oil as we would like to have, and if we can use it to better advantage we should certainly do so.

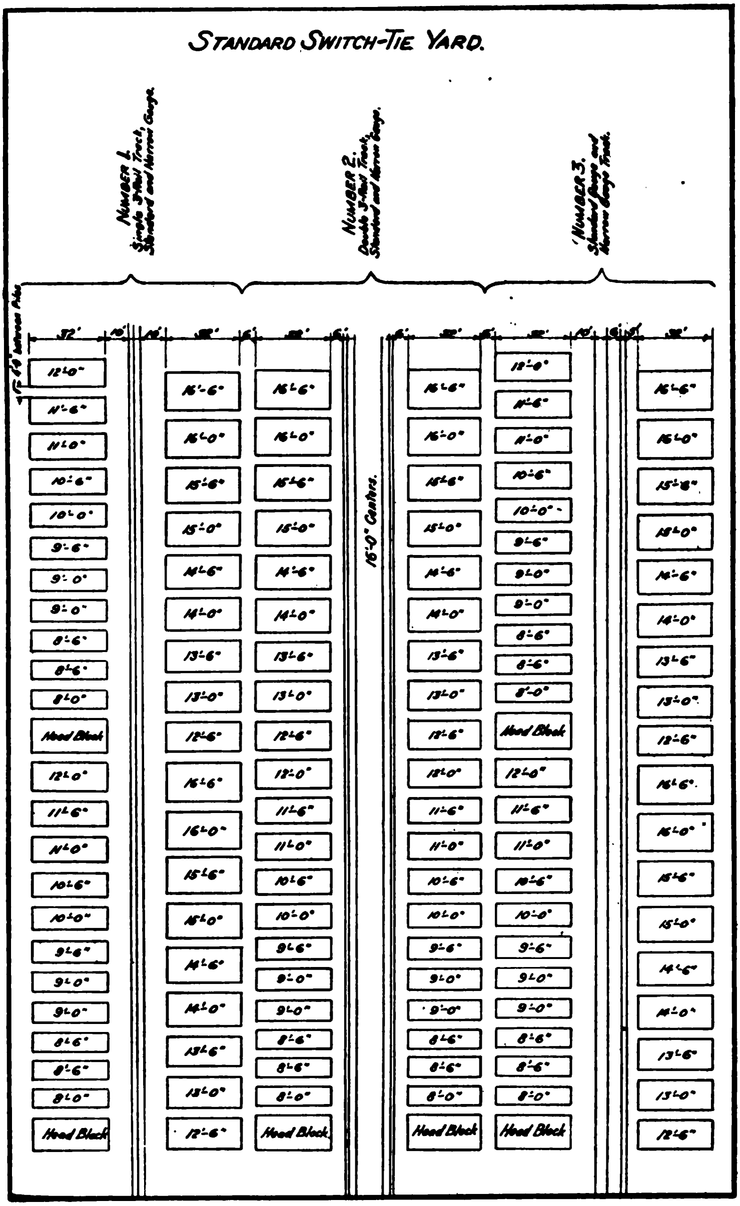
THE PRESIDENT: The next item is the Report of Committee No. 6-4 on Switch-Tie Yards.

REPORT OF COMMITTEE NO. 6-4—SWITCH-TIE YARDS.

To the Members of the American Wood-Preservers' Association:

Your Committee first wishes to call attention to the fact that it is possible to make recommendations for the laying out of switch-tie yards only in a very general way, due to the various kinds of sets used, the different variations, or breaks, in lengths, the size of the switch-tie used, etc., all of which have considerable bearing upon the type of yard which would be most convenient for any given set of conditions.

Your Committee feels that it is important in laying out a switch-tie yard, that all details be arranged to the end that as much


STANDARD SWITCH-TIE YARD.
NUMBER 1. Single 3-Rail Track, Standard and Narrow Gauge.
NUMBER 2. Double 3-Rail Track, Standard and Narrow Gauge.
NUMBER 3. Standard Gauge and Narrow Gauge Track.
4'-0" between Piles
32'
10'
10'
32'
6'
32'
6'
6'
32'
6'
32'
10'
6'
6'
32'
16'-0" Centers.
12'-0"
11'-6"
11'-0"
10'-6"
10'-0"
9'-6"
9'-0"
9'-0"
8'-6"
8'-6"
8'-0"
Head Block
12'-0"
11'-6"
11'-0"
10'-6"
10'-0"
9'-6"
9'-0"
9'-0"
8'-6"
8'-6"
8'-0"
Head Block
16'-6"
16'-0"
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of the handling as possible be done mechanically. A great many plants are using locomotive cranes to handle their switch-ties, others use the rubble car to aid in distributing the different length ties to the proper pile, and possibly there are plants using some type of power conveyor to move the switch-ties to and from the piles; at any rate, this is a possibility, and your Committee has endeavored to keep these things in mind in making this report.

Sketch shows a portion of 3 different switch-tie tracks: No. 1, a 3-rail track for tram cars and standard gauge cars; No. 2, 2 3-rail tracks 16-foot centers, and No. 3, standard and narrow gauge tracks side by side. In making this drawing it was assumed that the switch-ties were of 6-inch variation in length, and ranged from 8 feet to 16 feet 6 inches. It was also assumed that enough of the 8-foot 6-inch and 9-foot ties were handled to make it convenient to have 2 piles for each of these, to 1 pile of the other lengths. Obviously, if switch-ties of a 1-foot variation or break are to be yarded, a less number of piles would have to be provided per section of track; if 4-inch variation are to be handled, the section would require more piles.

No. 1 shows 10-foot clearance, rail to front of pile, to permit slewing of locomotive crane. If no crane is to be used it would be preferable to reduce this distance to 6 feet. It is thought best to arrange the piles so that part of the lengths are on one side of the track and part on the other, in this way reducing the distance to be traveled in distributing a carload of mixed lengths.

No. 2 consists of 2 3-rail tracks, and permits the use of locomotive crane for all handlings, the use of rubble care for distributing the various lengths of switch-ties to the proper piles when unloading cars by hand labor; also this arrangement seems to be favorable to the use of stackers (if possible, to mount them on cars or on wheels), the stackers to run on track next the material to be handled, while cars or trams are handled on opposite track.

No. 3 shows a narrow and standard-gauge track side by side. This arrangement permits the convenient use of locomotive crane for all handlings. In this arrangement, as in No. 1, it is thought best to arrange the piles so that a part of the lengths are on one side of the track and part on the other, to reduce the distance to be traveled in distributing a carload of mixed lengths.

Photograph Fig. 1 shows a satisfactory manner of piling untreated switch-ties for seasoning. The stripping is 4x4 car-stakes, which have been given a zinc treatment. This method is convenient for loading the ties from pile to trams with locomotive crane.

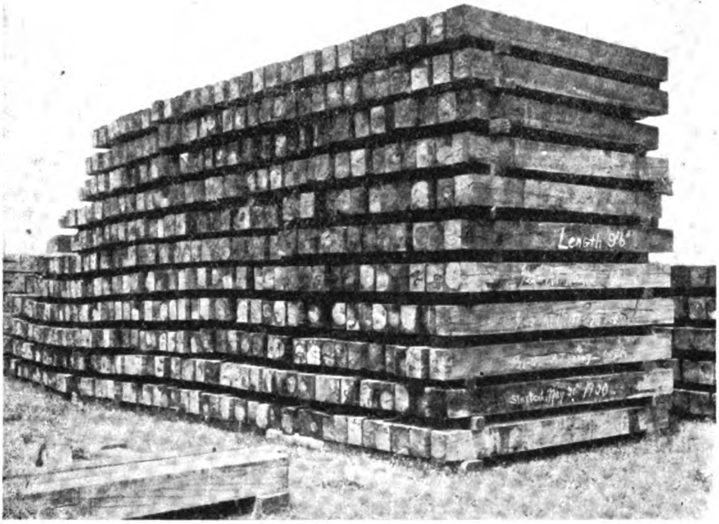

Fig. 1.—Method of Piling Untreated Switch-Ties for Seasoning.

Photographs 2 and 3 show a track of untreated switch-ties at one of the eastern plants. The stripping in this case is 2-inch treated material.

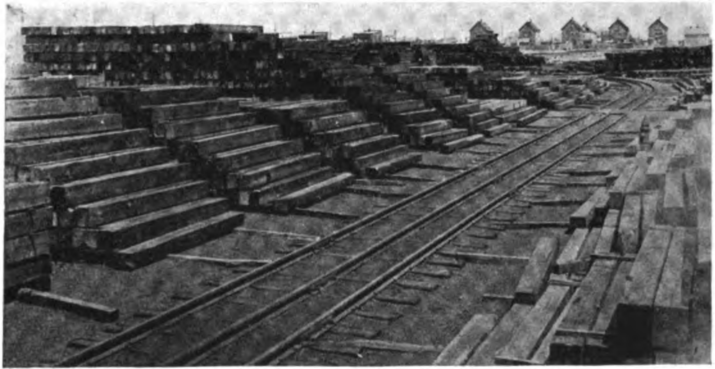

Fig. 2.—Untreated Switch-Ties at an Eastern Treating Plant.

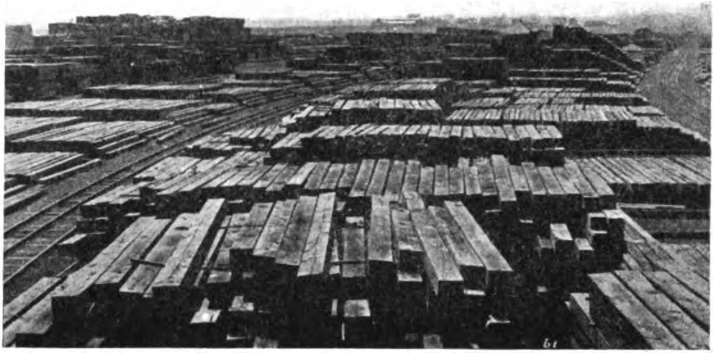

Fig. 3.—Another View of a Track of Untreated Switch-Ties at an Eastern Treating Plant.

In conclusion, your Committee want to emphasize the fact that practically everybody whom they consulted agrees that switch-ties ought to be piled in separate lengths, for the following reasons:

(1) Any length switch-tie needed can be gotten at quickly without extra handling.

(2) If switch-ties are loaded on trams in random lengths as many cubic feet cannot be loaded into a charge as can be done if each tram is loaded with only 1 length.

(3) Where it is required to ship switch-ties in sets they can be loaded more conveniently on the trams and handled at less cost. We admit it costs more to separate them when they are first unloaded on the yard, but this is more than offset by saving the cost of separating them from a pile of mixed lengths when the ties are ready for treatment.

R. S. **Belcher**, *Chairman.*
E. E. **Alexander.**
E. S. **Parks.**
J. H. **Waterman,**
General Chairman.

The President: The report of the Committee is now open for discussion.

Mr. J. H. Waterman: Mr. Chairman, there is a gentleman over here tonight who might give us some information on handling material by the traveling crane.

Mr. A. H. Onstad: Mr. President and Gentlemen, I did not expect to be called on for anything along this line, otherwise, I might have prepared something that might have been interesting. I was talking with Mr. Waterman yesterday, telling him what we have been doing in the way of handling lumber and timber without using as much main strength and awkwardness as is usually done around the timber yards.

About six years ago in building our mill at Everett we installed a bridge type crane for handling lumber instead of the usual method of using a locomotive type crane. After giving this thing some study we decided that we could also build a hook, or carrier, to attach to that crane whereby the operator up in the cage could take hold of the loads, transport them to the place where they were to be placed, set them down, and release them without the help of a ground man. We put that crane into operation serving our planing mill. The cycle of operation for that particular job it this: Along the mill sorter the lumber is piled on tram-cars similar to what you saw over at the Rutledge Timber Company at Cœur d'Alene, Idaho. After these cars are loaded they are switched by transfer cars similar to those used at Cœur d'Alene, except that they are electrically-driven, under the crane runway at one end of the runway. The crane then travels down over this, what you might call temporary storage yard, to the cars. The operator takes any unit off from any car he chooses, and takes it into the planing mill, and sets the unit down on a set of live rolls in front of the particular machine that will be used on that particular load of lumber.

We have not kept any real record as to what that crane can do in one day, but I do know of days when it has handled more than 600,000 ft. of lumber with only one man operating the crane.

Since that time we have made a similar installation at the mill at Snoqualmie Falls, Wash., which is working satisfactorily, and last summer we built a big retail yard in St. Paul, Minnesota. We have in this yard large sheds into which we put our yard stock sizes. All of the lumber of this kind shipped to this yard comes in box-cars, because it is such material as you wish to keep under cover. The lumber from these cars is loaded onto 2-wheel buggies, somewhat similar to those you have seen around the various mills on this trip.

We pile the lumber onto these buggies, into what we have determined as standard units—a unit being 4 ft. wide and 4 ft. high, and of a length of the particular stock handled. These units contain variable quantities—units of short length having say 1,800 board feet measure, while a unit of 2x4's 16 ft. long contains 3,800 board feet, and a unit of 2x4's 24 ft. long would contain 5,700 board feet.

These units, after being loaded on the buggies, are pushed under the crane-runway. The only care exercised in spotting the loads for the crane is to see that the unit is setting practically parallel to the crane-runway rail. When the crane comes along it picks this unit off the buggy, and puts it into a pile. We have adopted as a standard pile, one of 6 units high, making the pile, allowing for the spacers between units, 31 ft. from the ground to the top of the pile.

We have just completed a yard at Baltimore, Md., where we have built 2 sheds, each 76 ft. wide and 700 ft. long, each equipped with bridge type cranes. These sheds are so high that we will there also make our piles 6 units or 31 ft. high.

The results obtained in using cranes for handling lumber at our other plants have been so satisfactory that we adopted it for our new plant at Baltimore.

Our plans for Baltimore also call for a big timber shed. Here the timbers are to be handled by bridge type cranes.

We have designed a hook for use in handling timber, with the use of which the crane operator can, without the help of a ground man, take the timbers off a flat or gondola car, picking the timbers out one at a time, and placing them on the pile, or taking them out of the pile, and putting them onto a car without having strippers between the pieces to allow putting a sling around them. The idea is to take hold of the timbers by the 2 ends, and this hook as we have designed it, will automatically handle anything from 8 ft. long to 42 ft. long. It will also be possible to handle short lengths on a low pile between 2 high piles without leaving vacant spaces at each end for the hook, thus utilizing all of the floor space under the area covered by the crane.

We have not yet built one of these hooks, though I have made a model of it, based on a scale, 1 inch equals a foot, and having done quite a little experimenting with it am now making a larger model to see what difficulties we might have to overcome, so while we have not yet put this hook into operation we know it can be made to work, and we will make it work.

MR. J. H. WATERMAN: This statement that he has made is the most wonderful statement I ever heard on handling material in a material yard. I presume you all appreciate it. Just the man in the cage, or the operator, is the only help he has. I think those of us who have run up against the proposition of labor want to investigate that pretty thoroughly, because it seems to me they overcome what we have been trying to overcome in various other ways.

THE PRESIDENT: It may be of interest to know that recently a light type of gantry crane has been proposed for all tie and switch-tie yards. It is a good deal on the principle of the bridge type that Mr. Onstad speaks of, except that it is of light construction, without the overhead tracks. A number of us have been working on this proposition, and it is hoped that someone will be found with as much faith as Mr. Waterman has to go ahead and make it work.

Is there any further discussion? We will accept the report of the Committee with thanks.

Mr. Larkin, are you ready with your report on "Car Loading?"

MR. A. E. LARKIN: This was a sub-committee appointed to work under Mr. Waterman's general supervision to investigate the possibilities of loading box-cars with treated ties in any way other than the way this work is being done now generally throughout the country, namely, on the piece-work basis. Although this Committee has been in touch with a very great many people throughout the country, including a great many members of this Association and members of other associations, we have received invariably replies to the effect that no satisfactory method has been developed for loading closed cars with treated ties other than the method now in use. I will outline just one or two suggestions, and ask for some discussion of this problem, because it may be that someone with whom we did not correspond has developed some method of value in this connection.

There is one suggestion that has come out of the Metropolis plant of the Joyce-Watkins Company, and considering the size of that plant, the way it is operated, and the excellent work that is done there, any suggestion emanating from it should have our careful consideration. There has been some work done at this plant in connection with the building of a machine for putting ties from trams into cars. It has not been perfected as yet, but it contains some good points that should be considered in this connection.

It seems that they had the usual experience with labor in connection with this effort with which we are all familiar, namely, that the plant men refused to give any real assistance in the operation of the new machine which resulted in its not getting anything like a fair trial. [*Applause.*]

MR. R. L. ALLARDYCE: May I be allowed to make a suggestion? We have been handicapped in regard to labor conditions, and have built 3 tracks with 22-ft. centers, and handle our ties from the tram onto skid platforms. By doing this we are able to place the cars for loading and release the trams in about 45 minutes to an hour. This places the ties at the car-door, and the movement of the switch engine of 8 ft. will keep the ties right in front of the doors. Two men load the cars, an average loading car of about 2½ hours, 350 to 400 ties. By doing this we have increased the operations of the plant during this last year with its attending labor shortage. Our retort is very large. I believe it is the largest in the United States. But by the use of locomotive cranes we are handling hewn ties from 1,800 to 2,200 and sawn ties from 2,500 to 2,700 per charge, so you see we are up against the real proposition for labor. This has been a great help to us, and if this is of any benefit to the Association I would be glad to go into it further if anyone wants to discuss it.

THE PRESIDENT: Mr. Allardyce has some excellent pictures with him which I have had the pleasure of seeing, and I think that they show this operation very clearly. It has a further advantage which has not been mentioned in that the treated ties which come out of the retort hot may be immediately unloaded from the tram-cars and placed on these skids so that instead of holding the tram-cars loaded with treated ties until the load cool sufficiently to be handled by hand, they may be immediately unloaded and the ties stacked to be later skidded from the platforms into the cars. The photographs that Mr. Allardyce has shows this condition very clearly and from a plant operation standpoint, those of us who have been fighting the tram-car situation, and who know the necessity of having sufficient tram-cars on hand to keep loaded ties ready for the retort, will appreciate the fact that this means of taking the treated ties immediately after treatment and putting them on the skids simply means that we are able to double the number of effective trams that we have on the yard. At the price of tram-cars today any man who can cut his investment in half on an item like that has accomplished a great deal more than simply increasing the output of his plant. I think you gentlemen will be very glad to have the opportunity of getting a look at these photographs that Mr. Allardyce has.

MR. A. E. LARKIN: This arrangement does get the ties up shoulder high or waist high ready for loading, and to that extent it must facilitate the loading of ties in box-cars. It, however, does not deliver the ties from the yard into box-cars. I would like to ask Mr. Allardyce just what influence has this arrangement had on the cost of your loading.

MR. R. L. ALLARDYCE: There has been a heavy increase, including the increased cost of labor that we have had. We have had a good deal of friction in our labor districts, and it is not the cost of labor at the present time, but merely to release the trams as quickly as possible.

MR. A. E. LARKIN: Does it not reduce the cost of your loading?

MR. R. L. ALLARDYCE: It should reduce the cost but under the present conditions of labor it has not done so, but after labor gets plentiful we will be able to reduce our costs.

MR. A. E. LARKIN: In other words, it must be more attractive to the tie-handler in that position rather than to pick it up from the ground.

MR. R. L. ALLARDYCE: Yes, for the simple reason 2 men load the car instead of 4 men, you understand.

MR. A. E. LARKIN: There is a big reduction right there.

MR. R. L. ALLARDYCE: It costs just as much to handle cars with 2 men as with 4 men. If it cost you 3 cents a tie, it would cost you $3.00 a hundred, and 4 men would divide the $3.00, so it really would not cost you any more. The working conditions are much better, and as it appeals to the men they do more satisfactory work.

THE PRESIDENT: Is there any further discussion? If not, we will accept the report of Mr. Larkin as information. Thank you.

I will ask Mr. Keig's Committee to come forward and we will have the Report of Committee No. 5-9 on Inspection.

REPORT OF COMMITTEE NO. 5-9—INSPECTION.

To the Members of the American Wood-Preservers' Association:

History of Inspection.

The work of this Committee has not been without difficulties, because so far as we have been able to determine after extended search there never has been any endeavor to standardize inspection as we have attempted to do. In 1912 R. L. Allardyce presented a paper entitled "Inspections and Inspection of Material and Treatments at Commercial Plants," which contained valuable suggestions.

The United States Railroad Administration standardized five specifications for the preservative treatment of wood, which were adopted by the American Railway Engineering Association. Such specifications have prompted us to initiate the building of the procedure we recommend.

In the past many seemed of the opinion that the qualifications for a treatment inspector were few, the most important being his ability to make reports each day. This was erroneous. It is important that correct legible reports be made promptly, but this is not the inspector's principal duty by any means.

Analysis of Past Practice.

Our aims have been to attempt a uniform application of fundamental principles so that better results can be obtained. It is the work of years, to be started now and changed from time to time where it will benefit the industry to make changes through rejecting bad practices and perfecting good practices.

If we are to advance properly we ought to standardize our method of treatment. The industry is progressing with such leaps and bounds that we ought to develop practices now which will exclude the careless, lazy and visionary inspectors.

An all-important feature of any method of inspection is the necessity for capable and competent workers, and while it cannot be expected that in each and every case the inspector shall fill requirements in every respect we think it well to enumerate the qualifications and duties of a competent inspector.

We set only the standard at present practicable, and no doubt it will advance. Emergencies arise when it is not possible to avoid sending to a plant an inspector with a limited knowledge of the treating industry, yet whenever possible this should be avoided. The inspector with insufficient knowledge will usually either leave the entire supervision of the work to the treating company, or attempt to force them to perform the impossible, both of which tend to raise the price of the material to the consumer and make it harder for the inspector to get the proper result for his superiors.

Although plant officials make every effort to prevent discrepancies and accidents around the treating and cylinder room, there are times when they are unavoidable, due to new and inefficient help. The inspector if alive to his responsibility will know when the discrepancies occur and see that the proper allowances and adjustments are made so that his company may not suffer.

Recommendations for Plant Inspection With General Outline of Qualifications and Duties of Treatment Inspector.

The inspector should not spend the major portion of his time in the office, but rather his day should be divided in such a manner that he will spend most of his time in the treating room and the plant yard. He should be familiar with what is taking place in the treating room and the plant yard at all times, and whenever called upon be in position to know anything pertaining to conditions in the seasoning yard, treating room, or the plant in general.

The tendency of the time is toward an 8-hour day, yet an inspector who does not put in a full day and part of a night when necessary will not be abreast of what is being done for his company. Where a large volume of work is being turned out an inspector for day-work and an inspector for night-work are necessary.

Where departures from the specified requirements occur it is the duty of the inspector to refer these variations to his superior, so that his decision may be made with full knowledge of what is being done at the treating plant, and to transmit this decision of acceptance or rejection to the treating company. In other words, the inspector is not authorized to change specifications or instructions given him, unless beyond doubt his refusal to act before advising his superior would materially interfere with operations. In this case he should act to the best of his knowledge, advising his superior for future guidance.

In order to carry on successful inspection, the inspector should have at least a fair working knowledge of the various woods and their susceptibility to treatment. He should know when material is properly piled for seasoning. He should be able to determine when it is sufficiently seasoned for good treatment, and what forms of decay render material unsuitable for treatment.

The inspector need not be a chemist, although the training of one is a valuable asset, but he should have a practical working knowledge of the applied chemistry of the industry. In other words, he should be able to determine the water content of oil, to the grade of oil by fractional distillation, and make the tests necessary in treatment with zinc chloride solutions. He should also know when and how to sample the preservative used in the treatment of his material.

The efficient inspector should know the various processes used in the preservative treatment of wood; understand the reasons for and effects of steaming at various pressures and temperatures for various lengths of time, the effect of time required in the application of pressure and of drawing a vacuum for various periods on the penetration to be expected with a given amount of preservative, and the effect of the gravity of the preservative on the penetration.

He should acquaint himself with the various storage tanks in which the preservatives are kept, and the gauges or methods used in measuring their contents. He should also familiarize himself with the volume, temperature and pressure gauges, connected with the working tanks and cylinders. All of these instruments should be checked from time to time, in order that he may be able to vouch for their accuracy. Figures in use as to capacity of cylinders, working or storage tanks should be checked for the same purpose. An inspector should be in treating room as much as possible when timber is being treated, in order that he will be in a position to judge the rate of absorption and have sufficient knowledge when issuing instructions to treating plant engineer.

An inspector should familiarize himself with the equipment of the pump and cylinder rooms, such as pressure-pump, air-pump, water-pump, and also with all pipe-lines and valves.

He should be able to make corrections in the temperature of the preservatives, and to compute the number of gallons or pounds of preservative retained in a charge.

In the application of treating practices, it has been found that previous experience as a treating-plant engineer is of much value to the inspector.

The qualifications for a competent inspector might be outlined in the following manner :

I.—An inspector should have sufficient knowledge of the chemistry applied in the industry to :

- (1) Test for water content in oil. (Ref. 1.)
- (2) Test for grade of oil by fractional distillation. (Ref. 1, 27, 28, 29, 30.)
- (3) Test for strength and impurities of salt solutions. (Ref. 4, a.)
- (4) Test for percentage of oil in emulsions of solutions in oils, or oil compounds. (Ref. 1, 4, 5, 28, 29, 30.)
- (5) Sample the solution of oil being used. (Ref. 5, b.)
- (6) Determine gravity of oils and solutions. (Ref. 1.)
- (7) Determine effect of gravity of oil on penetration. (Ref. c. j.)

II.—Character.

An inspector should have a pleasing personality, and be diplomatic while protecting his employer's interests.

III.—Education.

1. The more schooling an inspector has had the more likely will he be to acquire sufficient education in the industry to know:
    - (*A) The various kinds of woods and their susceptibility to preservative treatment. (Ref. 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17.)
        - (a) The general requirements of the wood for the particular uses to which it may be put. (Ref. 7, 8.)

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*The Committee considers practical experience a most important factor in these qualifications.

(*B) When wood is properly seasoned for preservative treatment. (Ref. 5, 7, 9, 18, 19, 20.)
  (a) Moisture content test. (Ref. d, 30.)
  (b) Constant weight test. (Ref. e.)

(*C) How to determine the proper strengths of solutions, degree and duration of steaming, vacuum and pressure, etc., for a particular charge. (Ref. 5, 7.)

(D) How to determine absorption in a charge. (Ref. f.)
  (a) Correct the volume readings at working temperatures to volume readings at standard temperature. (Ref. 2, 5.)

(*E) How to test condition of devices in use to measure absorption. (Ref. g, 33, 34.)
  (a) Measurements of ullage or innage and comparison with gauges.

(F) How to calculate the capacities of cylinders, working and storage tanks. (Ref. 33, 34.)
  (a) Cubical content of cylinders with empty trams. (Ref. h.)
  (b) Cubical content of timber per cylinder load. (Ref. i, l.)
  (c) Capacity of working or storage tanks. (Ref. 33, 34.)

(*G) How and for how long to pile various woods for seasoning. (Ref. 5, 7, 8, 9, 18, 19, 20.)

(*H) The forms of decay that preclude possibility of practical treatment. (Ref. 3, 5.)

(I) The processes for preservative treatment of wood. (Ref. 1, 5, 6.)
  (a) Allardyce, zinc chloride and creosote.
  (b) Bethell, full-cell creosote.
  (c) Boiling, boiling in creosote.
  (d) Boulton, boiling under vacuum, creosote.
  (e) Burnett, zinc chloride.
  (f) Card, zinc chloride-creosote.
  (g) Lowry, empty-cell, creosote.
  (h) Rueping, empty-cell, creosote.
  (i) Reutger, zinc chloride-creosote.
  (j) Steaming, Colman process, creosote.
  (k) Wellhouse, zinc chloride-glue-tannin.
  (l) Brush treatment, preservative applied with brush.
  (m) Open-tank, preservative applied by dipping or bath.
  (n) Kyan, bath, mercuric chloride.

(J) The purposes and effects of the several steps in the various treatments. (Ref. 5, 7, 21, 22, 23, 24, 25, 26.)
  (a) Steaming, degree and duration.
  (b) Initial vacuum, degree and duration.
  (c) Pressure, degree and duration.
  (d) Final vacuum, degree and duration.

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*The Committee considers practical experience a most important factor in these qualifications.

IV.—Practice.

(1) An inspector should be industrious and in attendance at plant at all times.
  (A) Divide time between office, laboratory, yards and engine room.
  (B) In engine room at introduction of charge and completion of pressure period.
  (C) Familiarize himself with all mechanical equipment in use at a particular plant.
    (a) Pressure pump.
    (b) Vacuum pump.
    (c) Air pump.
    (d) Water pump.
    (e) Various pipe-lines.
    (f) Cylinders, etc.
  (D) Satisfy himself from time to time that gauges to indicate or record operations during treatment are correct.
    (a) Specially constructed test gauges.
    (b) Close observation.
  (E) Make tests for penetration.
    (a) Sample core. (Ref. j.)
    (b) Sample disc. (Ref. j.)
    (c) Visual methods. (Ref. 3, 31.)
    (d') Chemical analysis of borings by burning. (Ref. 1.)
    (e') Boiling of shavings or borings. (Ref. j.)
  (F) Take inventory of preservatives on hand. (Ref. k, 1 and 3.)
  (G) Familiarize himself with methods in use for transferring or putting up solutions and oils to be used.

Treating Operation.

The treating operation should be reported as follows:

All readings to be taken from working-tank gauges or scales. In computing net absorption, containing salt solutions, the mean temperature of readings I and V will be used. In computing net absorption, containing oil or oil compounds, the temperature used will be correct to 100° F.

I. Reading and temperature before filling voids in treating cylinders.
II. Reading after filling voids in treating cylinder.
III. Reading when pressure period is completed.
IV. Reading after first return of preservative to working tank.
V. Reading and temperature after final return of preservative to working tank.

'Borings or shavings may be taken from sample disc or material proper.

Example in tank feet corrected for temperature.

I.	Reading	from	working	tank	14.65
II.	"	"	"	"	9.65
III.	"	"	"	"	8.70
IV.	"	"	"	"	13.55
V.	"	"	"	"	13.60

(1) Reading I minus II is volume required to fill voids in treating cylinder as well as partially fill voids in the wood, namely: 14.65 minus 9.65 equals 5.00, volume required to fill voids.

(2) Reading II minus III equals volume absorbed during pressure period, namely, 9.65 minus 8.70 equals 0.95, volume absorbed during pressure period.

(3) Reading II minus III this result minus results in V minus [†]I equals initial absorption; namely, 9.65 minus 8.70 equals 0.95
14.65 minus 13.55 equals 1.10
1.10 minus 0.95 equals 0.15 initial absorption.

(4) Reading I minus V equals net absorption, namely, 14.65 minus 13.60 equals 1.05 net absorption.

(5) Reading IV minus III equals volume in the voids of treating cylinder. Compute to cubic feet and subtract from volume of cylinder (in cubic feet), the result will be cubic feet of wood in charge computed by displacement, namely,
13.55 minus 8.70 equals 4.85
4.85 times 420 square feet (working-tank area) equals 2037 cubic feet, volume in voids of treating cylinder.
3337 cubic feet (volume of treating cylinder, containing cylinder cars and appliances) minus 2037 cubic feet equals 1300 cubic feet, timber in charge by displacement.

The thanks of the Committee are extended to those who have gladly rendered assistance in the preparation of this report.

Methods or Rules Used in Inspection.

(See Outline of Inspector's Qualifications.)

(a[‡]) Simple test for determining impurities in zinc chloride solution.

Iron.—Take sample of solution in use, place in test tube, add small quantity of ammonia and shake well. If there is a reddish brown flocculent precipitate, it indicates the presence of iron.

[†] This outline to be adjusted to meet conditions at various plants, and for the different processes.

[‡] The Committee realizes that these tests would be but superficial, and that more complete results would be obtained by a competent chemist in a well-equipped laboratory.

Free Acid.—Take sample of 2% or 3% solution, fill test tube three-fourths full, fill balance of tube with one one-thousandth solution methyl orange. If the combination shows a reddish cast, the solution contains free acid; if it shows a yellow cast, it proves the absence of free acid.

Sulphate.—Take sample of 2% or 3% solution, place in test tube, add a small quantity of barium chloride. If the result is a milky white precipitate, it indicates presence of sulphate, or barium sulphate.

(b) Sampling salt solutions in working tank and during treatment.

Solution should be thoroughly agitated with air for at least 15 minutes before sample is taken from working tank, and should be taken shortly before introduction to treating cylinder, from pet cock or valve conveniently located in side of tank, or by means of thief.

Solution of oil and zinc chloride should be heated to treating temperature before obtaining sample.

Samples taken during treatment should be obtained from pipe-line during filling period, or from pump during pressure period.

(c) The effect of gravity of oil on penetration.

This would be determined best by means of sample disc or core obtained from material treated by oil in question. (See j.)

(d) Determination of seasoning period of wood by moisture content test.

Sample should be taken with brace and bit, or increment borer, at center of ties or timber, at various parts of the pile. Borings should be caught in a wide salt mouth bottle, and capped at once after boring is made.

In sampling, 40 grams to 50 grams should be taken, which is usually obtained after making five borings on different sides of pile.

In taking samples from red oak ties, always bore in 4 inches or one-half diameter of tie. If diameter is 10 inches, then take 5-inch sample.

In pine and gum, make borings only in sapwood, when heart borings begin to show reject same.

Take bottle containing borings and weigh on scale or balance. (Which is used in weighing for creosote distillations.) After carefully weighing, the borings are run in a tin dish sufficiently wide that when all sample is contained therein it will not be over 1 inch in depth. This allows the heat to get to all parts of the sample readily and drying it uniformly.

Place the tin container with borings in a copper oven on shelf near the top, and heat, bringing the temperature up to 102° C. to 108° C. as soon as possible.
After reaching 100° C., heat the sample 4 hours, never to exceed 108° C., then remove and place the dry borings in sample bottle, and weigh.

During the first hour or so in heating, it is a good plan to open door of oven several times to allow the moisture or steam to escape, allowing door to remain open 10 seconds or so is usually sufficient.

After reaching 105° C., open door once more, then let remain closed until operation is finished.

Bottle should be weighed empty; subtract this weight from weight of bottle and wet borings, and you have weight of wet borings.

Subtract weight of bottle and dry borings from weight of bottle and wet borings. This equals weight of moisture in wood.

Divide weight of moisture in wood by weight of wet borings. This will give per cent of moisture in ties or material.

(e) Determining seasoning period of wood by constant weight method.

A certain amount of material is weighed and piled for seasoning, then weighed at stated periods until a constant weight is reached, or as near that condition as practicable.

This method would, of course, only be used to get data on certain material in various localities and under different climatic conditions; it would not be considered for practical use.

(f) Figuring absorption in charges; various processes.

Bethell.
Let
A=Tank gauge reading before introducing.
B=Tank gauge reading after completing forcing back.
C=Tank feet of oil injected into charge.
D=Gallons per tank foot.
E=Gallons of oil injected into charge.
F=Gallons of oil injected into charge after making corrections for temperature.
G=Weight per gallon of oil.
H=Pounds of oil injected into charge.
I =Cubic feet of timber in charge, calculated or estimated.
J =Pounds of oil per cubic foot of timber.

$$
\begin{aligned}
A - B &= C \\
C \times D &= E \\
F \times G &= H \\
H \div I &= J
\end{aligned}
$$

Burnett.

Let
A = Tank gauge reading before introducing.
B = Tank gauge reading after completing forcing back.
C = Tank feet of solution injected in charge.
D = Area of tank.
E = Cubic feet of solution injected into charge.
F = Average weight of solution per cubic foot.
G = Pounds of solution injected into charge.
H = Strength of solution.
I = Pounds of pure zinc injected into charge.
J = Cubic feet of timber in charge, calculated or estimated.
K = Absorption per cubic foot of timber.
L = Volumetric absorption.

$A - B = C$
$C \times D = E$
$E \times F = G$
$G \times H = I$
$I \div J = K$
$E \div J = L$

Card.

Let
A = Tank gauge reading before introducing.
B = Tank gauge reading after completing forcing back.
C = Tank feet of emulsion injected into charge.
D = Area of tank.
E = Cubic feet of emulsion injected into charge.
F = Proportion of oil in emulsion.
G = Weight of oil per cubic foot.
H = Pounds of oil injected into charge.
I = Proportion of zinc chloride solution in emulsion.
J = Strength of zinc chloride solution.
K = Pounds of pure zinc injected into charge.
L = Cubic feet of timber in charge, calculated or estimated.
M = Absorption of oil per cubic foot of timber.
N = Absorption of pure zinc per cubic foot of timber.
O = Volumetric absorption.

$A - B = C$
$C \times D = E$
$E \times F \times G = H$
$E \times I \times J = K$
$L \div H = M$
$L \div K = N$
$E \div L = O$

Lowry.

Let
A = Tank gauge reading before introducing.
B = Tank gauge reading after returning oil to tank.
C = Tank feet of oil injected into charge.
D = Gallons per tank foot.
E = Gallons of oil injected into charge.

F = Gallons of oil injected into charge after making corrections for temperature.
G = Weight per gallon of oil.
H = Pounds of oil injected into charge.
I = Cubic feet of timber in charge, calculated or estimated.
J = Pounds of oil per cubic foot of timber.
K = Gallons of oil injected per cubic foot.
L = Cubic feet per tie, calculated or estimated.
M = Gallons of oil injected per tie.

$A - B = C$
$C \times D = E$
$F \times G = H$
$H \div I = J$
$F \div I = K$
$K \times L = M$

Rueping.

Let
A = Tank gauge reading before introducing.
B = Tank gauge reading after completing forcing back.
C = Tank feet of oil injected into charge.
D = Gallons per tank foot.
E = Gallons of oil injected into charge.
F = Gallons of oil injected into charge after making corrections for temperature.
G = Weight per gallon of oil.
H = Pounds of oil injected into charge.
I = Cubic feet of timber in charge, calculated or estimated.
J = Pounds of oil per cubic foot of timber.

$A - B = C$
$C \times D = E$
$F \times G = H$
$H \div I = J$

(Method given for figuring Bethell process can be adjusted to meet requirements of other processes not given.)

(g) Checking measuring devices in use to measure absorption.

(1) Working tank, float-gauge (reading either in gallons, cubic feet or tank feet.) Obtain interior measurements of working tank. If vertical tank, figure capacity per tank foot. Measure ullage with gauger's bob and tape, chalking gauge-bob so mark between water and oil will show. Compute innage, and compare with reading on indicator board. Check this at three different levels. See if gauge mechanism is functioning properly, that is, float, cable, pulley and weight with indicator. See that float, working tank and grooves on indicator board are clean.

(2) Working tank, mercury-gauge or dial-gauge.—Obtain interior measurements of working tank, and figure capacity in gallons, per tank foot. When

working tank is not in use measure ullage, and compute innage. Then see if innage corresponds with gauge readings. Try this at three different levels, and obtain check.

(3) Working-tank scales.—
Check with yard platform scales. Weigh charge before and after treatment with platform scales. The difference in the weight should correspond with the difference in weight shown on working-tank scales before and after treating. Occasionally check platform scales with test-weight or test-weight car.

(h) Cubical content of cylinder with empty trams.

I. (1) Figures used as volume of working tanks should be checked for their accuracy; also gauges used to measure quantities used from working tanks. (See g.)

(2) Cylinder should be free of all debris or at least represent an average condition in that respect.

(3) Run train of empty trams and appliances in cylinder, close door. These trams should be representative of trams in daily use.
Take careful reading of gauges and thermometers on working tank.

(4) Fill cylinder from working tank with oil, zinc chloride solution or solution of oil and zinc chloride under vacuum (this should be as near a perfect vacuum as possible). When it is definitely known that cylinder is full take a careful measurement of amount used to fill cylinder, compute to cubic feet; this amount will represent cubical content of cylinder with empty trams.

Oil or solution of zinc chloride and oil should be at temperature in use or as near that figure as possible, and corrections made to standard temperature where necessary.

Measurements can be taken by direct reading of gauge by ullage determination, or by scale weight.

II. Calibration of inside area of cylinder, making all allowances for rail, rivets, bolts, heating coils, lapping of sheets, empty trams and appliances, etc. Allowances should also be made for volume of pipeline back to shut-off valve.

(i) Cubical content of timber per cylinder load to be used as constant figure.

I. Cubical content by displacement should be obtained on each cylinder load of material treated during a period of at least 2 weeks (see 5, treating operation), which should include if possible a complete cycle in weather conditions.

Inspector should keep an accurate record of each operation in the treating process. This should not be considered a test period, but rather a record of actual working conditions, and when figures are completed they should typify an average cubical content per cylinder load applicable under all conditions.

If it is not customary to load trams to full capacity they should not be loaded otherwise during this period.

If as a general rule a special effort is not made to make up full trains for treatment it should not be done at this time.

This figure to be used in treatment of hewn timber. Sawn timber to be figured according to actual dimensions. The so-called "Santa Fe" volume table to be used for piles and poles.

II. Actual measurement of material covering period of at least 2 weeks, which should include a complete cycle if possible of all varying conditions.

(j) Determining average depth of penetration.

I. (1) Wait until charge has cooled.

(2) Select samples from the species that represent major portion of the charge.

(3) Select average samples of this species in respect to seasoning (proportion of heart and sapwood) and density (number of annual rings per inch).

(4) Be sure that the increment borer or the saw is clean.

(5) Obtain disc or core samples from representative species, taking sample midway between the middle and the end of the piece at right angles to the longitudinal surface, and as near the center of the width and thickness as possible. Bear in mind when making penetration test the use to which the timber is to be put, especially contact and wearing points. Plug all test holes with treated plugs.

(6) If the average depth of penetration of the sample discs or cores thus procured is satisfactory it is assumed that material has received satisfactory treatment.

(7) This method is applicable to both creosote and zinc chloride treatment. The chemical color reaction tests will be used to indicate penetration of zinc chloride.

II. Boiling or borings.

Secure sample or borings, as outlined above (see I), place small quantity in beaker, add distilled water, place over flame, and boil for short time. Filter water into test tube, add a small amount of sodium carbonate; this will cause precipitation of zinc chloride as zinc carbonate, or in other words the appearance of milk curdle.

This test of course, is principally to indicate presence of zinc chloride in sample.

(k) Method of taking inventory.

Amount of preservatives on hand in various working, storage, transfer tanks and sumps, etc., should be measured by gauger's bob and steel-tape or rod, then computed into pounds or gallons, making corrections for temperature and allowances for water in oil where necessary.

Tank cars will also be measured. However, as a rule they are not considered on hand unless unloaded.

Measurements may also be taken by direct reading of gauges, if they have been checked for their accuracy.

If weight readings are taken the gravity of the preservative must be recorded.

Inventory should be taken at least once a month, and checked against amounts used daily.

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RECOMMENDATIONS FOR FUTURE COMMITTEE WORK.

(1) Take up treatment practices in detail with respect to the several processes; various species of wood, and different classes of material.

(2) When and where to take temperatures of preservative in use, and effect of temperature on treatment.

(3) Advisability of standard forms.

(4) Study plant equipment with the idea of making helpful suggestions.

J. R. KEIG, *Chairman.*
J. M. BLACK
J. H. CAMPBELL
E. T. DAVIES
F. N. GRAHAM
T. J. MCGINTY
C. M. TILLEY
J. H. TRACY

THE PRESIDENT: You have heard the excellent report of this Committee. Is there any discussion? If not, we will accept the report of the Committee with the thanks of the Association.

We will now call for the Report of Audit Committee, Mr. Hunt (Chairman).

MR. GEO. M. HUNT: Mr. Chairman, the Committee has examined the books of the Secretary-Treasurer, and found them correct.

THE PRESIDENT: With this report in hand we will accept the report of the Secretary-Treasurer which was presented to us at our opening session.

We will call for the Report of the Resolutions Committee, Mr. Ford (Chairman).

MR. C. F. FORD: The Committee on Resolutions desires to submit the following:

RESOLUTION NO. 1.

> *Whereas,* National legislation is needed to adequately protect the remaining timber supplies of the United States and to insure their perpetuation, to provide for cooperation between the Federal and State governments in such protection, and to provide for the acquisition of forest land by the United States.
>
> *And Whereas,* There was introduced into Congress on December 20, 1920, the Snell Bill, which has for its object the accomplishment of the above purposes,
>
> *Be It Resolved,* By the American Wood-Preservers' Association, in Annual Meeting assembled at San Francisco, January 25-27, 1921, endorses the proposed legislation and urges its members to help bring about its enactment into law.

RESOLUTION NO. 2.

> *Whereas,* The excellent research work in wood preservation which has been done by the United States Forest Service, in its Forest Products Laboratory, at Madison, Wisconsin, has contributed much to the development of technique in our industry, and
>
> *Whereas,* There remain problems which the Laboratory can cooperate in solving to the benefit of all our citizens through conserving the products of the forests by preservative treatment, and
>
> *Whereas,* The work of the Laboratory is seriously handicapped by lack of sufficient funds to carry on investigations and experiments in wood utilization,
>
> *Be It Resolved,* By the American Wood-Preservers' Association in Annual Meeting assembled at San Francisco, January 25-27, 1921, that this Association urge Congress to provide moneys sufficient to permit the work of the Forest Products Laboratory to proceed as planned by its worthy officers.

MR. C. F. FORD: The Committee moves the adoption of these resolutions.

MR. F. N. GRAHAM: I second the motion.

THE PRESIDENT: All in favor respond by saying "aye;" contrary, same sign; it is so ordered.

Gentlemen, during the reading of the next 3 Resolutions you will please rise.

(The Members then arose while the following Resolutions were read.)

RESOLUTION No. 3.

Whereas, Death has taken from our numbers our worthy member, Edmund M. Blake, in the midst of his strenuous labors as Chairman of the Entertainment Committee for this meeting, and as Fiscal Agent and one of the leading spirits of the San Francisco Bay Marine Piling Committee whose report was one of the features of the meeting, and

Whereas, Mr. Blake, although a recent member of this Association, has shown such a striking personality, and has devoted himself so unsparingly, and with such ability and energy to the interests of this Association, and

Whereas, The securing of the hearty hospitality extended to this Association by the people of San Francisco and the Pacific Coast, and the unanimous good-will and effective work of the San Francisco Bay Marine Piling Committee were especially on the heart of Mr. Blake,

Therefore Be It Resolved, That the American Wood-Preservers' Association record its keen sense of loss in the death of Mr. Blake, and tender to the relatives and business associates of the deceased its heartfelt sympathy in their bereavement, and

Be It Resolved Further, That the Secretary forward a copy of these Resolutions to the family and business associates of Mr. Blake.

RESOLUTION No. 4.

Whereas, Death has removed from our midst, our worthy member, Charles C. Higgins,

Be It Resolved, That the American Wood-Preservers' Association tender the relatives of the deceased heartfelt sympathy in their bereavement, and

Be It Resolved Further, That the Secretary forward a copy of these condolences to the family of Mr. Higgins.

RESOLUTION No. 5.

> *Whereas,* Death has removed from our midst, our worthy member, Russell A. Griffin,
>
> *Be It Resolved,* By the American Wood-Preservers' Association tender the relatives of the deceased heartfelt sympathy in their bereavement, and
>
> *Be It Resolved Further,* That the Secretary forward a copy of these condolences to the family of Mr. Griffin.

The Committee moves the adoption of these Resolutions.

MR. J. H. WATERMAN: Second the motion.

THE PRESIDENT: It is so ordered.

The Secretary has been instructed to formally acknowledge the appreciation of the American Wood-Preservers' Association to those associations along the way which contributed so largely to making our trip to San Francisco a pleasant one.

We will now have the report of the Election Tellers, Mr. Wyman (Chairman).

MR. R. L. WYMAN: Members of the American Wood-Preservers' Association, there was cast a total of 209 ballots in the recent election. A careful check of these ballots by the Tellers shows that the following members were elected as officers:

For President, Mr. C. M. Taylor. [*Applause.*]

For First Vice-President, Mr. F. J. Angier. [*Applause.*]

For Second Vice-President, Mr. H. S. Valentine. [*Applause.*]

For Secretary and Treasurer, Mr. G. M. Hunt. [*Applause.*]

For the Executive Committee, Mr. H. S. Sackett and Mr. R. J. Calder. [*Applause.*]

For the Nominating Committee, Mr. G. A. Colman, Mr. J. H. Durham, Mr. L. T. Ericson, Mr. P. Harris, Mr. R. H. Rawson and Mr. E. Stimson, total six. [*Applause.*]

THE PRESIDENT: Gentlemen, it now becomes my very pleasant duty to ask Mr. Grow to escort Mr. Taylor to the Chair, and while he is doing it I want to say that no President of the American Wood-Preservers' Association has ever had more splendid cooperation than I have had during the past year, and I am indebted to all of you, and particularly to Mr. Taylor. [*Applause.*]

MR. C. M. TAYLOR: Ladies and Gentlemen, I assure you it is a pleasure to accept the honor from the hands of Mr. Joyce and you members. I trust the Association will prosper this year as it has in the last, and I want to impress upon you the fact that this is not a one-man association. While I may be President, you are the members of the Association, and it is only the cooperation of each one of you, whether you are a young member or an old member, that will make this Association prosper and be what it should be in this country.

The fact that we have met in San Francisco shows that we should cover this whole country, and it certainly has been fine to meet and enjoy the members from the Pacific Coast in a way that we have never had the opportunity before, and I trust that each one of you will thank the Entertainment Committee and the members of San Francisco and the Pacific Coast for the wonderful entertainment that we have enjoyed at their hands. And I trust that the impression made by our members among the Pacific Coast people will be such that we will have many of them at our convention next year and the years to come. [*Applause.*]

As is always the case Mr. Angier is on the job; it is not necessary to have anybody escort him, Mr. Angier. [*Applause.*]

MR. F. J. ANGIER: Mr. President and Gentlemen, I believe there is an unwritten law that the Vice-President is not required to make a speech. I want to say only a few words, however. I am a Charter Member of this Association, and have been Secretary for 11 years. During that time I have, as you all know, had a lot of work to perform, but I have enjoyed the work. In leaving the office of Secretary-Treasurer to accept that of the First Vice-President, I am not unmindful of the honor that you have conferred upon me, and I want to say to you that I will accept that honor and will do all I can for the upbuilding of the Association.

To my successor, Mr. Hunt, I wish him everything that is good, and I will promise to help him in every way that I can.

To the members of the Association who have written to me so many times for information, I hope they will not forget me and will continue to write, and so long as I can, I will be very glad indeed to answer any letters and help you in every way possible. I thank you. [*Applause.*]

MR. C. M. TAYLOR: It is too bad Mr. Valentine could not be here to make a speech of acceptance, but I know that he will work hard and consistently as he has always done. If I remember rightly, Mr. Valentine is the first officer of the second generation in wood preservation. Some of you do not know that Mr. Valentine's father was one of the early pioneers in wood preservation. It was due to his father's good work that we are so firmly established on the Atlantic Coast, and it seems fitting that his son should now become an officer of the Association.

Mr. Cooper, would you be kind enough to escort Mr. Hunt to the front? [*Applause.*]

MR. GEO. M. HUNT: Mr. President and Members of the Association, I appreciate that it is an honor to be Secretary of this Association especially after the office has been given the prestige which the retiring Secretary has given it. I am fully aware, however, that the office of Secretary is no joke and that my principal job for the coming year will be to "saw wood and say nothing," and that is what I expect to begin to do right now. [*Applause.*]

MR. J. H. WATERMAN: Mr. Chairman, if you will allow me to say a word, I would like to say somthing for our friend, Angier. Gentlemen, he has served this Association as he has told you, but I want to tell you he has been faithful; there is not a man in this Association that he does not know by name, and I think it is due him at this time that we should give him a rising vote of thanks for the services he has rendered the Association. [*Applause and all the members rise.*]

MR. F. J. ANGIER: Gentlemen, I thank you for that. It has repaid me for all that I have done. [*Applause.*]

MR. C. M. TAYLOR: The next order of business is the selection of the 1922 meeting place. We all realize we would like to come back to San Francisco next year, but we have no invitation as yet.

(The Secretary read the invitations that were received.)

MR. GEO. M. HUNT: That covers all the written invitations.

MR. C. M. TAYLOR: What is your pleasure?

MR. J. H. WATERMAN: At the last convention I had the pleasure of moving that we go to San Francisco. However, Chicago is the natural place for a convention of this kind. Let me give you one or two reasons. There is a man sitting in front of me who represents one of the commercial industries of this country, and has long been a member of this Association. He is the only one attending the convention at San Francisco. He told me a minute ago that if the convention was in Chicago they would have at least 7 men, if not 9 men, in attendance. The men can come from New York and as far west as the Rocky Mountains; they can come from the south in a little over a night, and I feel the majority of your men will agree with me that it is the easiest place that we can reach with the least travel,—that we can have the largest number of men. It is fine to go to California. There is no place like California on the map. California is the only California in the United States, but Chicago is the place for the next convention if we want to reach the young men. Everybody can not afford to come here, but most anyone can afford to go to Chicago. Therefore, I move you that our next convention be held in the city of Chicago.

MR. WALTER BUEHLER: I second the motion.

MR. C. M. TAYLOR: All in favor say "aye;" opposed, like sign. We will meet in Chicago in 1922.

Has any member at this time any suggestion to make for the welfare of the Association?

Let me again impress on you the fact that it is your Association to do with as you see fit in order to promote wood preservation to the fullest extent. We want the cooperation of everyone. The officers this year will be present to accept the advice, as is the case of all presidential nominees this year,—of all level-headed minds. We want suggestions that will improve the Association, and I trust that you will work to the betterment of our industry.

Mr. Angier spoke in his Secretary's report at the opening meeting of the fact that if each member would get one new member we would have a total enrollment of 600. I trust that you will live up to his suggestion. The Pacific Coast has been wonderfully alive to this problem this year, and has gotten a large number of members. We have pretty well canvassed the Chicago territory, but it is interesting to note that there are a number of men in the industry in and around Chicago that are not members as yet. Please see to it that they become members this coming year.

Are there any other suggestions?

We adjourn in this room at this time to enable the National Association of Railway Tie Producers to meet at 1:30. They have asked that I on behalf of their Secretary extend the privilege of their floor to the members of the American Wood-Preservers' Association, and I trust that you will take advantage of their invitation. Several of them have been with us through all of our sessions, and I feel that the cooperation that we have had is in the right direction. They need our support, and we need theirs.

MR. J. H. JOHNSON: I wish to say on behalf of a number of members of the National Association of Railroad Tie Producers that we have appreciated the courtesy of the members of your Association on this trip. We have been in the minority as to numbers, but we have had a very delightful time. You have taken us right in with you, which we have appreciated very much, and we certainly would be very glad to have you attend the opening meeting of our Association this afternoon; also our sessions tomorrow if you can possibly arrange to do so. [*Applause.*]

MR. C. M. TAYLOR: Are there any other suggestions? If not, we will stand adjourned until 1922.

STATISTICAL
DATA

QUANTITY OF WOOD TREATED AND PRESERVATIVES USED IN THE UNITED STATES IN 1920.

By R. K. Helphenstine, Jr., United States Forest Service

The American Wood-Preservers' Association
In Cooperation with the United States Department of Agriculture,
Forest Service, William B. Greeley, Forester; Office of
Forest Products, H. S. Betts, Engineer in
Forest Products, in Charge.

Summary.

A total of 173,309,505 cubic feet of wood was subjected to preservative treatment in the United States in 1920 by the 112 treating plants that were active. The quantity treated represents an increase of 27,248,511 cubic feet, or 18% over the quantity that was reported by the 108 plants that were engaged in the industry in 1919.

Quite an increase was registered in the number of cross-ties treated. In 1920 the total number reported was 44,987,532, as compared to 37,567,927 the year previous. During the year covered by this report 11,965,912 linear feet of piles were given preservative treatment, or less by 1,591,607 linear feet than were reported in 1919. The number of poles treated in 1920 was 585,781, which represents an increase of 207,300 poles over the number treated in 1919. A total of 2,568,156 square yards of wood blocks were run through the cylinders in 1920, representing an increase of 772,469 square yards over the quantity reported by the treating plants in 1919. A decrease was registered in the quantity of construction timbers treated, the 1920 figure being 139,749,738 board feet as compared with 144,742,477 board feet the year previous. The number of cross-arms reported by the plants as having been treated in 1920 was over 4 times as many as were treated in 1919, and the quantity of lumber and miscellaneous material impregnated with preservatives also showed a substantial increase.

In 1920 there were consumed by the treating plants of this country 68,757,508* gallons of creosote, 1,848,911 gals. of paving oil and 1,772,084 gals. of miscellaneous preservatives. In addition 49,717,929 pounds of zinc chloride were used. The quantity of zinc chloride employed by the treating plants during the year represents the largest amount of this preservative ever before reported by the industry, and constitutes an increase of 6,234,795 lbs. over the 1919 consumption.

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*Includes imported oil, distillate coal-tar creosote, coal-tar creosote solution, refined water-gas tar, and water-gas tar solution.

The quantity of creosote used in 1920 represents an increase of 3,201,261 gals. over the quantity used in 1919, while the paving oil consumption was less than for the year before by 563,681 gallons. The quantity of miscellaneous preservatives used during the year was over 15 times as much as was consumed in 1919.

Source of Statistics.

In 1920 there were 112 treating plants in active operation in the United States, or 4 more than reported the year before. From all but 2 of these the Forest Service obtained complete signed statements showing the extent of their operations during the period covered by this report. Two plants failed to supply the data wanted, and in order to make the statistics as nearly complete as possible estimates for these plants were prepared. Table 1 shows by classes and types the number of plants which were active, idle or abandoned in 1920. The table also shows the number of new plants that were built during the year.

TABLE 1.—TREATING PLANTS IN THE UNITED STATES BY CLASSES AND TYPES. 1920.

Status	Commercial Plants			Railroad Plants			Private Plants			Total
	Pressure	Non-pressure	Pressure and Non-pressure	Pressure	Non-pressure	Pressure and Non-pressure	Pressure	Non-pressure	Pressure and Non-pressure	
Active (old)...	59	8	2	26	0	1	4	9	1	110
Active (new)..	1	1	0	0	0	0	0	0	0	2
New (inactive).	2	0	0	0	0	0	0	0	0	2
Idle..........	3	0	2	1	0	0	0	2	0	8
Abandoned....	1	0	0	0	0	0	1	0	0	2
Total......	66	9	4	27	0	1	5	11	1	124

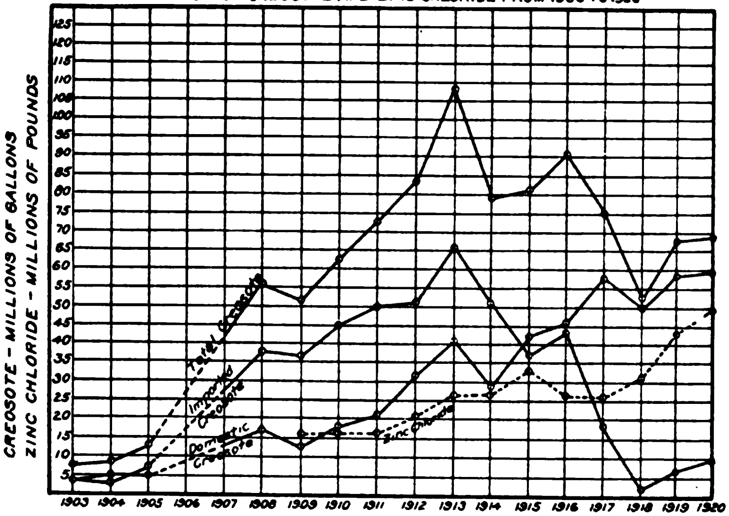
The majority of the treating plants in this country, as shown in Table 1, are of the pressure-cylinder type. Although the data presented in this report is based largely upon the figures furnished by such plants, it also includes those secured from non-pressure plants. The activities of only those plants which maintain regular treating plant equipment is, however, covered by this report. No attempt has been made to include brush treated material or that treated with temporary equipment in small amounts for special purposes. A considerable amount of material is no doubt treated in this way, but because consumers of this character are so numerous it would be a difficult matter to collect statistics concerning them.

The value of these statistics is now well recognized, not only by the wood-preserving industry, but also by the principal classes of users of treated wood, including railroads, steamship companies, light and power plants and municipalities.

Progress of the Industry.

In 1909 there were in the United States a total of 64 active treating plants. In 1920 there were 112 plants in operation, or nearly double the number that were in existence 12 years ago.

PROGRESS OF WOOD PRESERVATION IN THE UNITED STATES
CONSUMPTION OF CREOSOTE AND ZINC CHLORIDE FROM 1903 TO 1920



Note: Figures for Creosote not available for years 1906 and 1907 nor for Zinc Chloride prior to 1909

OFFICE OF FOREST PRODUCTS
U.S. FOREST SERVICE

Each year 1 or 2 plants go out of existence and several new ones start operation. In 1920 there were 2 plants that were abandoned while 4 new ones either started operations or were constructed during the year, representing a net gain over the year before of 2 plants. This is an evidence of the gradual growth of the industry in this country. Another indication of growth is the added consumption of preservatives from year to year by the treating plants, and the more general use of treated wood by farmers, home-builders and others representing the general public. Furthermore in 1920 there were 173,309,505 cubic feet of wood treated by the plants of the United States. This exceeded the quantity reported in 1919 by 27,248,511 cu. ft., and constitutes the largest quantity ever before reported by the industry.

Consumption of Preservatives.

In Table 2 are shown comparatively for the years 1909 to 1920 inclusive, the number of treating plants in active operation and the amount of the various classes of preservatives which they used. In 1920, as was the case in 1919, the material reported as creosote was separated into 4 classes, namely, distillate coal-tar creosote, creosote coal-tar solution, refined water-gas tar, and water-gas tar solution, the total consumption of the 4 combined being 68,757,508* gals., or 3,201,261 gals. more than was reported in 1919.

The quantity of paving oil used in 1920 was less than the amount consumed the year previous by 563,681 gals., while the amount of miscellaneous preservatives reported by the industry during the year exceeded the 1919 consumption by 1,670,073 gallons. This extensive increase in this class of preservative was due to the fact that there were used during the year over 800,000 gals. of crude oil for diluting creosote.

In 1920 the treating plants used 49,717,929 lbs. of zinc chloride, the largest quantity ever before reported by the industry. This amount exceeded the 1919 consumption by 6,234,795 pounds. Of the total quantity used by the plants during the year, 28,364,113 lbs. were reported as fused and 42,707,632 lbs. in the form of 50% solution.

Although the supply of preservatives of various kinds used by the treating plants in 1920 was apparently more or less plentiful the prices of some of them still remained high, in comparison with the prices that were current prior to the war. The range of prices current during the year for the different classes of preservatives used are shown in Table 3.

With the return of ocean transportation to a point more nearly approaching normal, an increase in the importation of foreign oil was to be expected. Table 4 shows the actual amount of creosote oil that was imported into this country each month of 1919 and 1920. It will be noted that the 1920 importation totaled 18,427,152 gals., or 7,158,773 gals. more than was obtained abroad during the previous year. The quantity of foreign oil reported as having been used by the treating plants during the year covered by this report was 9,575,680 gals., or 8,851,472 gals. less than was actually

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*Includes imported oil, distillate coal-tar creosote, coal-tar creosote solution, refined water-gas tar and water-gas tar solution.

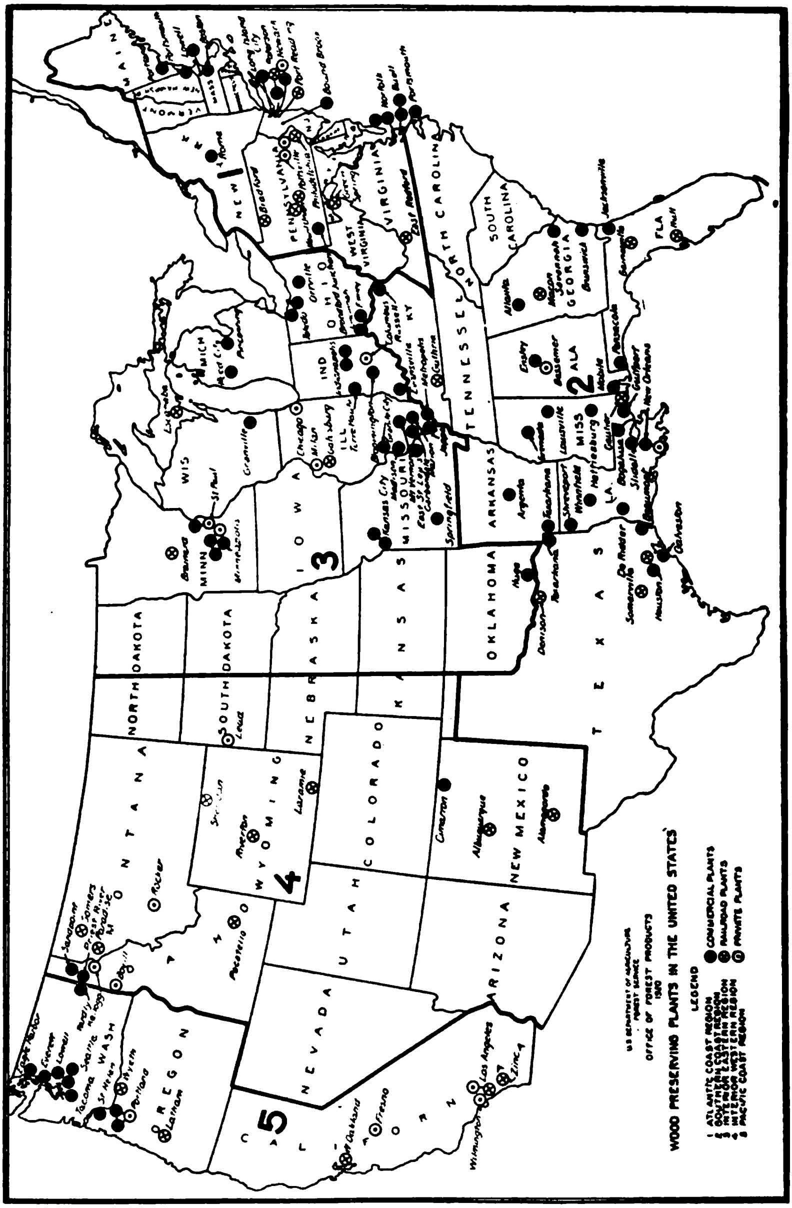
TABLE 2.—CONSUMPTION OF WOOD PRESERVATIVES BY THE TREATING PLANTS OF THE UNITED STATES, 1909-1920.

Year	Number of Plants	Creosote						Paving Oil	Zinc Chloride	Other Preserva-tives
		Distillate Coal-tar Creosote	Creosote Coal-tar Solution	Refined Water-gas Tar	Water-gas Tar Solution	Imported	Total			
		Gallons	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Pounds*	*Gallons*
1909.....	64	(a)	(a)	(a)	(a)	37,569,041	51,426,212	(a)	16,215,107	(b)
1910.....	71	(a)	(a)	(a)	(a)	45,081,916	63,266,271	(a)	16,802,532	2,333,707
1911.....	80	(a)	(a)	(a)	(a)	51,516,706	73,027,335	(a)	16,359,797	1,000,000
1912.....	84	(a)	(a)	(a)	(a)	52,531,295	83,666,490	(a)	20,751,711	3,072,462
1913.....	93	(a)	(a)	(a)	(a)	66,673,192	108,373,359	(a)	26,466,803	3,885,738
1914.....	94	(a)	(a)	(a)	(a)	51,307,736	79,334,606	9,429,444	27,212,259	2,486,637
1915.....	102	(a)	(a)	(a)	(a)	37,501,007	80,859,442	3,205,563	33,269,604	1,693,544
1916.....	117	(a)	(a)	(a)	(a)	43,649,931	90,404,749	5,675,095	26,746,577	582,754
1917.....	115	(a)	(a)	(a)	(a)	18,259,141	75,541,737	7,579,819	26,444,689	137,361
1918.....	107	(a)	(a)	(a)	(a)	2,165,736	52,776,386	4,057,862	31,101,111	28,013
1919.....	108	24,286,851	31,292,661	1,148,084	2,334,727	6,493,974	65,556,247	2,412,592	43,483,134	102,011
1920.....	112	25,483,230	27,921,614	1,377,702	4,399,282	9,575,680	68,757,508	1,848,911	49,717,929	1,772,084

(a) Statistics for years 1909 to 1918, inclusive, not separated.
(b) Statistics not available.

TABLE 3.—PRICES PAID FOR PRESERVATIVES IN 1920.

Region		Distillate Coal-tar Creosote	Creosote Coal-tar Solution	Refined Water-gas Tar	Water-gas Tar Solution	Zinc Chloride 50 Per Cent Solution	Zinc Chloride Fused
		Per gallon	*Per gallon*	*Per gallon*	*Per gallon*	*Per pound*	*Per pound*
Atlantic Coast........	1919	$0.12 to .15	$0.11 to .25	$0.0375 to .10	$ 0.065	$0.04 to .048	....
	1920	.15 to .25	.11 to .20	.09 to .24	0.08 to .15	.04 to .0433	$0.08 to .0825
Southern Coast......	1919	.11 to .21	.10 to .25	.07	....	....	.074 to .09
	1920	.10 to .295	.109 to .20	.10 to .20	.15	.04 to .0415	.0729 to .09
Interior Eastern......	1919	.13 to .213	.12 to .135	.0631 to .10	.08	.0327 to .075	.0725 to .09
	1920	.098 to .45	.093 to .25	.0631 to .10	.08 to .15	.0343 to .0415	.068 to .1085
Interior Western.....	1919	.10 to .40	.113 to .25	....	....	....	.065 to .08
	1920	.121 to .50	.161 to .29	....	....	.0417	.079 to .0942
Pacific Coast.........	1919	.244 to .288	.157 to .32	....	....	....	.075 to .087
	1920	.18 to .28	.35	....	....	.0425 to .043	.075 to .08


U S DEPARTMENT OF AGRICULTURE
FOREST SERVICE
OFFICE OF FOREST PRODUCTS
1910
WOOD PRESERVING PLANTS IN THE UNITED STATES
LEGEND
1 ATLANTIC COAST REGION
2 SOUTHERN COAST REGION
3 INTERIOR EASTERN REGION
4 INTERIOR WESTERN REGION
5 PACIFIC COAST REGION
● COMMERCIAL PLANTS
⊗ RAILROAD PLANTS
⊙ PRIVATE PLANTS
1
2
3
4
5
MAINE
VERMONT
MASS
NEW YORK
PENNSYLVANIA
N J
WEST VIRGINIA
VIRGINIA
NORTH CAROLINA
SOUTH CAROLINA
GEORGIA
FLA
OHIO
IND
KY
TENNESSEE
ALA
MISS
LA
MICH
WIS
ILL
MISSOURI
ARKANSAS
MINN
IOWA
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MONTANA
WYOMING
COLORADO
NEW MEXICO
IDAHO
UTAH
ARIZONA
NEVADA
WASH
OREGON
CAL
Portsmouth
Lowell
Boston
Long Island City
Bound Brook
Rome
Bradford
Norfolk
East Radford
Jacksonville
Atlanta
Macon
Savannah
Brunswick
Fernandina
Pensacola
Mobile
Gulfport
New Orleans
Bessemer
Laurel
Hattiesburg
Shreveport
Texarkana
Argenta
Bogalusa
Beaumont
Houston
Galveston
Somerville
Denison
Hugo
Chicago
Granville
St Paul
Minneapolis
Brainerd
Kansas City
Springfield
East St Louis
Terre Haute
Galesburg
Guthrie
Metropolis
Orrville
Escanaba
Reed City
Laramie
Riverton
Lead
Albuquerque
Alamogordo
Cimarron
Pocatello
Sandpoint
Somers
Paradise
Bonner
Seattle
Tacoma
Everett
Portland
Latham
Oakland
Fresno
Los Angeles
Wilmington
Tampa

imported. The difference is accounted for by the fact that no doubt some imported oil bought in 1920 was still on hand at the close of the year. The balance probably was purchased in small quantities for the brush treatment of wood or was used by paint manufacturers for creosote shingle stains or in the preparation of proprietary preservatives.

TABLE 4.—MONTHLY IMPORTS OF FOREIGN CREOSOTE, 1919-1920.*

Month	1919	1920
	Gallons	*Gallons*
January	142,789	3,002,222
February	252,165	45,295
March	217,563	236,942
April	5,200,281	972,664
May	2,226,024	42,222
June	130,069	939,878
July	213,121	988,173
August	214,961	3,529,697
September	113,981	1,044,252
October	133,898	5,226,884
November	132,965	2,347,681
December	2,290,617	51,292
Total	11,268,379	18,427,152

*Figures of Bureau of Foreign and Domestic Commerce.

Table 5 shows comparatively the quantities of foreign and domestic creosote used in each year from 1909 to 1920, inclusive.

TABLE 5.—RELATIVE QUANTITY OF DOMESTIC AND IMPORTED CREOSOTE USED BY THE TREATING PLANTS OF THE UNITED STATES, 1909 TO 1920.

Year	Domestic		Imported		Total Used
	Gallons	*Per Cent.*	*Gallons*	*Per Cent.*	*Gallons*
1909	13,862,171	27	37,569,041	73	51,426,212
1910	18,184,355	29	45,081,916	71	63,266,271
1911	21,510,629	29	51,516,706	71	73,027,335
1912	31,135,195	37	52,531,295	63	83,666,490
1913	41,700,167	38	66,678,192	62	108,378,359
1914	28,026,870	35	51,307,736	65	79,334,606
1915	43,358,435(a)	54	37,501,007	46	80,859,442
1916	46,754,818(b)	52	43,649,931	48	90,404,749
1917	57,282,596(c)	76	18,259,141	24	75,541,737
1918	50,610,650(d)	96	2,165,736	4	52,776,386
1919	59,062,273(e)	90	6,493,974	10	65,556,247
1920	59,181,828(f)	86	9,575,680	14	68,757,508

(a) 41,333,890 gallons coal-tar creosote and 2,024,545 gallons water-gas tar.
(b) 45,318,735 gallons coal-tar creosote and 1,436,083 gallons water-gas tar.
(c) 54,305,204 gallons coal-tar creosote and 2,977,392 gallons water-gas tar.
(d) 47,787,998 gallons coal-tar creosote and 2,822,652 gallons water-gas tar.
(e) 24,286,851 gallons distillate coal-tar creosote; 31,292,661 gallons creosote coal-tar solution; 1,148,034 gallons refined water-gas tar, and 2,334,727 gallons water-gas tar solution.
(f) 25,483,230 gallons distillate coal-tar creosote; 27,921,614 gallons creosote coal-tar solution; 1,377,702 gallons refined water-gas tar, and 4,399,282 gallons water-gas tar solution.

Of the 9,575,680 gals. of foreign oil reported as having been used by the plants in 1920, 233,196 gals. came from Canada, 687,203 gals. were obtained from Germany, and 8,655,281 gals. were shipped in from England.

Regional Division of the Wood-Preserving Industry.

As has been the case in past years in the compilation of statistics on wood preservation in the United States, the entire country has been separated into 5 regions. These regions, which are shown on the accompanying map, were originally selected for the reason that the areas embraced in them more nearly conform to the Forest Service subdivision into which the country's original forests have been divided. Table 6 gives the figures for these regions and shows comparatively for 1919 and 1920 both the quantity of preservatives consumed and the amount of material treated by the plants embraced in each region.

Preservatives Consumed and Material Treated.

ATLANTIC COAST REGION.

In this region 22 plants were active in 1920, as compared with 20 in 1919. They consumed 18,109,246 gals. of creosote, or the second largest quantity reported by any of the regions. Of the quantity used, 17,269,246 gals. were of domestic production and 840,000 gals. were imported. These plants also consumed 1,804,339 lbs. of zinc chloride and 160,250 gals. of miscellaneous preservatives.

The plants of this region reported the treatment of 5,675,741 cross-ties, of which 4,036,877 were hewed and 1,638,864 sawed.

The region reported the treatment of 2,589,375 linear feet of piles, or less by 614,691 lin. ft. than were treated by the same plants in 1919. These plants also subjected to treatment 18,472 poles, representing more than twice the number reported the year previous.

A slight increase was registered in the quantity of wood-blocks treated. In 1920 the number of square yards reported was 184,176 as compared with 124,501 in 1919.

The region ranked second in the treatment of construction timbers, the quantity reported being 22,730,703 board feet.

Over 4 times as many cross-arms were treated by the plants of the Atlantic Coast Region in 1920 as were subjected to treatment the year before, while the quantity of miscellaneous lumber reported for the year was 2,676,663 board feet, or over twice as much as were treated in 1919.

TABLE 6.—PRESERVATIVES USED AND MATERIAL TREATED IN THE UNITED STATES IN 1919 AND 1920.

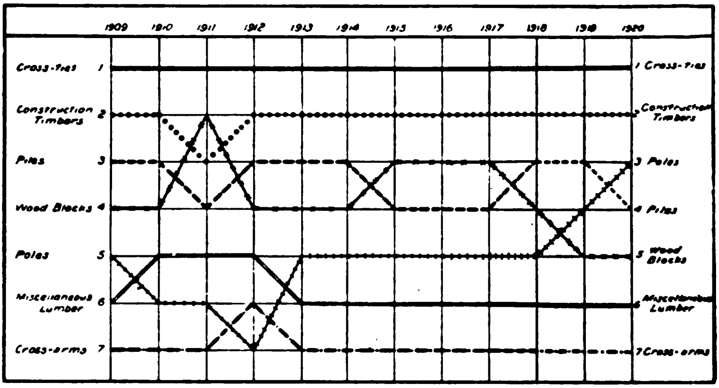
Region	Year	Number of Plants	Creosote		Zinc Chloride	Paving Oil	Other Preservatives	Cross-ties		Piles	Poles	Wood Blocks	Construction Timbers	Cross-Arms	Miscellaneous
			Domestic (a)	Imported				Hewed	Sawed						
			Gallons	*Gallons*	*Pounds*	*Gallons*	*Gallons*	*Number*	*Number*	*Lin. ft.*	*Number*	*Sq. yd.*	*Bd. ft.*	*Number*	*Bd. ft.*
Atlantic Coast	1919	20	17,720,709	1,471,206	1,686,910	300,000	73,815	3,770,390	1,765,641	3,204,066	8,352	124,501	25,903,710	5,619	1,251,258
	1920	22	17,269,246	840,000	1,804,339	....	160,250	4,036,877	1,638,864	2,589,375	18,472	184,176	22,730,703	25,475	2,676,663
Southern Coast	1919	29	22,363,886	3,618,384	13,657,532	112,592	....	10,085,593	2,206,162	7,917,469	64,214	258,787	80,848,998	115,216	3,621,858
	1920	31	24,476,974	5,269,270	18,957,246	298,911	464,703	13,793,332	2,199,461	6,259,484	140,018	629,982	79,513,756	382,699	4,905,704
Interior Eastern	1919	31	14,864,554	890,761	15,449,158	2,000,000	24,016	11,301,291	3,255,464	322,445	184,430	1,250,394	20,738,498	....	2,157,230
	1920	31	14,019,917	173,439	20,313,143	1,550,000	497,575	13,373,127	3,842,155	298,556	262,297	1,725,842	22,176,786	105,768	4,957,914
Interior Western	1919	12	1,164,732	266,380	4,371,623	....	3,950	1,049,131	2,079,867	102,905	21,327	2,475	9,819,701	672	52,039
	1920	13	1,770,286	21,649	4,946,467	....	646,271	1,996,290	1 ,515,686	185,320	102,483	1,670	10,447,261	268	119,163
Pacific Coast	1919	16	2,948,392	247,243	8,317,911	....	230	455,872	1,598,516	2,010,634	100,158	158,530	7,431,570	....	1,031,244
	1920	15	1,645,405	3,271,322	3,696,734	....	3,285	100,713	2,581,027	2,633,177	62,511	26,486	4,881,232	....	2,204,830
Total	1919	108	59,062,373	6,493,974	43,483,134	2,412,592	102,011	26,662,277	10,905,650	13,557,519	378,481	1,795,687	144,742,477	121,507	8,113,629
	1920	112	59,181,828	9,575,680	49,717,929	1,848,911	1,772,084	33,300,339	11,687,193	11,965,912	585,781	2,568,156	139,749,738	514,210	14,864,274

(a) Includes distillate coal-tar creosote, creosote coal-tar solution, refined water-gas tar, and water-gas tar solution.

SOUTHERN COAST REGION.

In point of quantity of creosote used the plants of this region have always occupied first place. The 31 plants which were active in the region led again in this respect in 1920 with a consumption of 29,746,244 gals., of which 24,476,974 gals. were of domestic manufacture, and 5,269,270 gals. were imported. The quantity of imported oil used represents the largest amount reported by any of the regions. These plants also consumed the second largest quantity of zinc chloride, amounting to 18,957,246 pounds. They also used 464,703 gals. of miscellaneous preservatives.

RELATIVE RANK OF THE SEVEN CLASSES OF MATERIAL TREATED 1909-1920



The plants of the Southern Coast Region treated 15,992,793 cross-ties, the second largest number reported by any of the 5 regions. Of the number treated, 13,793,332 were hewed ties, and 2,199,461 sawed ties.

This region led in the treatment of piles, the quantity reported being 6,259,484 lin. ft., and although only 140,018 poles were subjected to treatment by the plants of the region during 1920, this number was over twice the quantity reported in 1919.

This region also ranked first in the treatment of construction timbers and cross-arms. Of the former there were 79,513,756 board feet, and of the latter 382,699 pieces. The region ranked second in the treatment of wood-blocks, the quantity reported being 629,982 square yards.

In addition to the material mentioned above, the plants of this region treated 4,905,704 board feet of miscellaneous lumber.

INTERIOR EASTERN REGION.

Thirty-one plants, the same number that reported in 1919, were active in this region in 1920. They consumed 14,193,356 gals. of creosote. Of this quantity, 173,439 gals. consisted of imported oil and the balance was of domestic manufacture. These plants consumed 20,313,143 lbs. of zinc chloride, again taking first place in the consumption of this preservative. They also used 1,550,000 gals. of paving oil, the largest quantity reported, and in addition 497,575 gals. of miscellaneous preservatives.

This region led all others in the treatment of cross-ties, the number that were run through the cylinders being 17,215,282. Of the total number treated, 13,373,127 were hewed and 3,842,155 sawed ties.

In 1920 the plants of the Interior Eastern Region treated 298,556 lin. ft. of piles and 262,297 poles. The quantities of these two classes of material that were treated during the year represent slight increases over the amounts reported in 1919.

This region treated 1,725,842 square yards of wood-blocks, thereby taking the lead over all other regions in the treatment of this class of material. It also took first place in the treatment of miscellaneous lumber, the quantity reported being 4,957,914 board feet.

In addition to the material already mentioned, the plants of the region treated 22,176,786 board feet of construction timbers and 105,768 cross-arms.

INTERIOR WESTERN REGION.

In 1919 there were 12 plants in active operation in this region, while in 1920 there were 13. These plants consumed 1,791,935 gals. of creosote, or 360,823 gals. more than was used in the same region the previous year. Of the total quantity employed in the preservative treatment of wood during the year, 21,649 gals. were of foreign, and 1,770,286 gals. of domestic manufacture. These plants also used 4,946,467 lbs. of zinc chloride, and occupied first place in the consumption of miscellaneous preservatives, the total quantity which they reported being 646,271 gallons.

In this region 3,511,576 cross-ties were treated during the year covered by this report, or 382,978 more than were treated in 1919. Of the total number reported 1,996,290 were hewed and 1,515,686 sawed ties.

These plants treated 185,320 lin. ft. of piles, and 102,483 poles, the latter item representing an increase of 81,156 poles over the number reported in 1919.

The plants of the Interior Western Region also treated 1,670 square yards of wood-blocks, 10,447,261 board feet of construction timbers, 268 cross-arms, and 119,163 board feet of miscellaneous lumber.

PACIFIC COAST REGION.

Fifteen plants, or 1 less than were active in 1919, reported in connection with the preparation of the 1920 statistics. They used 4,916,727 gals. of creosote consisting of 1,645,405 gals. of domestic oil, and 3,271,322 gals. of foreign manufacture. They also consumed 3,696,734 lbs. of zinc chloride, and 3,285 gals. of miscellaneous preservatives.

In this region there were subjected to treatment a total of 2,681,740 cross-ties, of which 2,581,027 were sawed, and 100,713 hewed.

These plants subjected to treatment 2,633,177 lin. ft. of piles, and 62,511 poles, the former representing 622,543 lin. ft. in excess of the quantity reported in 1919.

The plants of the Pacific Coast Region also treated 26,486 square yards of wood-blocks, or 133,044 square yards less than were reported the year before. In addition they also subjected to treatment 4,881,232 board feet of construction timbers, and 2,204,830 board feet of miscellaneous lumber.

Preservation of Ties.

A glance at Table 9 will show that for all the years for which these statistics have been gathered, cross-ties have always constituted the bulk of the material treated. In 1920 the 112 treating plants that were active in this country reported a total of 173,309,505 cu. ft. of wood as having been given preservative treatment. Of this quantity nearly 80%, or 134,962,596 cu. ft., consisted of cross-ties. The number of cross-ties treated in 1920 was 44,987,532, or 7,419,605 more than the 37,567,927 reported the year before. Of the total quantity treated, 33,300,339 were hewed, and 11,687,193 sawed.

Yellow pine ties again ranked first, the number treated being 16,621,773. Oak ties occupied second place with 14,531,848, while Douglas fir ties to the number of 3,861,514 were third. The number of ties of each kind of wood that were reported, the percentage of the total which each represents, and the number treated with the different preservatives used are shown in Table 7.

TABLE 7.—CROSS-TIES TREATED, BY KINDS OF WOOD AND KINDS OF PRESERVATIVES—1920.

Preservative	Oak	Yellow Pine	Douglas Fir	Western Pine	Beech	Gum	Tamarack	Maple	Birch	Elm	Hemlock	All Other	Total
Creosote (1).....	4,833,161	5,656,534	341,785	201,663	776,142	80,562	188,307	500,910	491,739	....	88,706	262,008	13,371,517
Zinc chloride....	8,735,184	10,297,540	3,508,056	1,592,644	1,344,914	868,428	364,000	608,073	429,021	506,419	477,626	401,815	29,132,720
Zinc chloride and creosote (2).	963,503	667,699	....	....	341,607	89	47,420	231,772	1,500	....	133,906	84,126	2,471,622
Miscellaneous...	....	....	11,673	....	....	....	....	....	....	....	....	....	11,673
Total.......	14,531,848	16,621,773	3,861,514	1,794,307	2,462,663	949,079	549,727	1,340,755	921,260	506,419	700,238	747,949	44,987,532
Per cent of total.	32.3	36.9	8.6	4.0	5.5	2.1	1.2	3.0	2.0	1.1	1.6	1.7	100.00

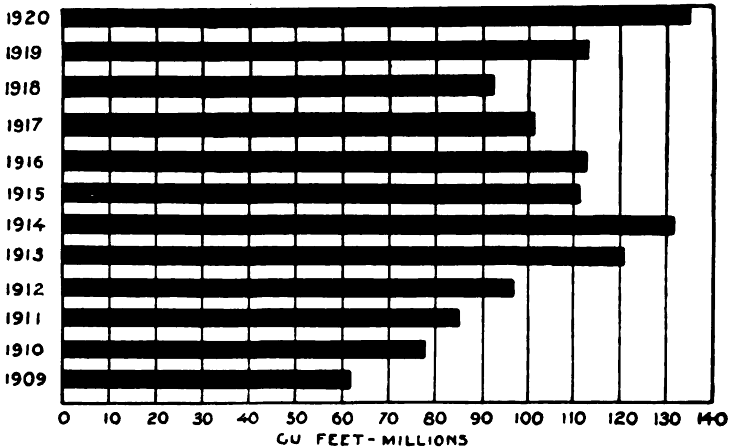
(1) Includes distillate coal-tar creosote, creosote coal-tar solution, refined water-gas tar and water-gas tar solution.
(2) Includes distillate coal-tar creosote, creosote coal-tar solution, refined water-gas tar and water-gas tar solution in mixture with zinc chloride.

In Table 8 are presented statistics showing the number of cross-ties treated in 1920 by classes and types. As indicated in this table, the bulk of the ties treated are those intended for use on steam railroads. Of the total number of ties of this type that were reported 1,579,552 were adzed, 295,577 bored, 8,249,591 both adzed and bored, and 32,552,019 neither adzed nor bored. Of the electric railroad ties, 36,434 were adzed, none were bored, 141,563 both adzed and bored, and 2,132,796 neither adzed nor bored.

TABLE 8.—CROSS-TIES TREATED IN 1920, BY CLASSES AND TYPES.

Class	Adzed	Bored	Adzed and Bored	Not Adzed or Bored	Total
Steam railroads.......	1,579,552	295,577	8,249,591	32,552,019	42,676,739
Electric railroads.....	36,434	....	141,563	2,132,796	2,310,793
Total..........	1,615,986	295,577	8,391,154	34,684,815	44,987,532

The number of cross-ties treated with zinc chloride in 1920 was 29,132,720, while less than half as many, or 13,371,517, were impregnated with creosote. The zinc-creosote emulsion was used in the preservative treatment of 2,471,622 ties, and 11,673 were treated with miscellaneous preservatives.



CROSS-TIES TREATED

For those ties treated with creosote* an average absorption of 7.33 lbs. per cubic foot was obtained. In treating ties with zinc chloride the average amount of this preservative forced into the wood per cubic foot was 0.49 pound. Where the zinc-creosote emulsion was employed, the average injection per cubic foot amounted to 0.50 lb. of zinc chloride and 4.6 lbs. of oil.* The Bethell, Burnett, Boiling, Card, Colman, Lowry, Rueping and open-tank processes were all used in the treatment of cross-ties.

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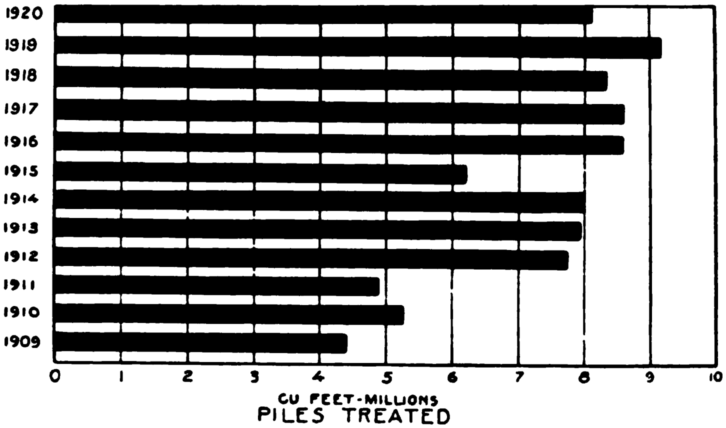
*Includes distillate coal-tar creosote, creosote coal-tar solution, refined water-gas tar and water-gas tar solution.

Preservation of Piles.

The treating plants of the United States reported the treatment in 1920 of a total of 11,965,912 lin. ft. of piles, which constitutes a decrease of 1,591,607 lin. ft. from the quantity treated in 1919. The piles treated consisted principally of southern yellow pine and Douglas fir. The plants of the Southern Coast Region again lead in the treatment of this class of material, with a total of 6,259,484 lin. ft., while the Pacific Coast Region was second with 2,633,177 linear feet. The Atlantic Coast Region ranked third with 2,589,375 linear feet.



PILES TREATED

Piles were treated with creosote* alone and also with the zinc-creosote emulsion. With the first-mentioned preservative an average of 14.10 lbs. per cubic foot were forced into the wood. In treating piles with zinc and creosote in combination an average of 0.538 lb. of the former and 3.21 lbs. of the latter constituted the absorption obtained per cubic foot. The Bethell, Boiling, Card, Colman, Lowry and Rueping were the processes used.

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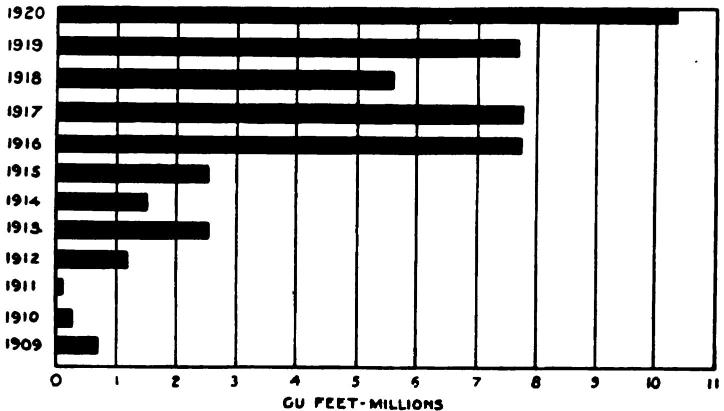
*Includes distillate coal tar creosote, creosote coal-tar solution, refined water-gas tar and water-gas tar solution.

Preservation of Poles.

The number of poles treated in this country in 1920 was 585,781, or 207,300 more than were subjected to treatment the year previous. These statistics cover only those poles treated with the equipment maintained at regular pressure and open-tank treating plants. They do not include brush-treated poles, or those treated with purely make-shift or temporary apparatus.

The principal pole species treated were, in the order of their importance according to quantity reported, western red cedar, northern white cedar, and southern yellow pine. A few poles of chestnut and other woods were also reported treated.



POLES TREATED

Creosote* was the preservative used in the treatment of practically all poles reported, the average absorption obtained by the Bethell, Lowry and Rueping processes being 12.65 lbs. per cubic foot. In addition to the pressure processes mentioned, the open-tank process was also employed to a very large extent in treating poles.

Preservation of Wood-Blocks.

The number of square yards of wood-blocks treated by the plants of the United States in 1920 was 2,568,156. The quantity reported represents an increase over the quantity treated in 1919 of 772,469 square yards. Of the total quantity treated 764,640 square yards were intended for outside paving, and 1,803,516 square yards for inside flooring.

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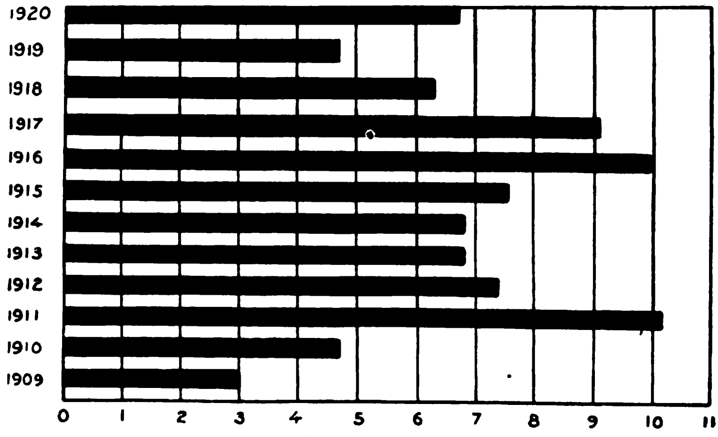
*Includes distillate coal-tar creosote, creosote coal-tar solution, refined water-gas tar and water-gas tar solution.

Creosote* and paving oil were the preservatives used in treating wood-blocks. The average injection of preservative per cubic foot for those blocks intended for use as inside flooring was 8.90 lbs., while for blocks to be used for outside paving it was 15.03 pounds. The Bethell, Boiling, Lowry and Rueping were the processes used.



WOOD-BLOCKS TREATED

Preservation of Construction Timbers.

In this report heavy structural material, such as bridge and dock timbers, switch-ties, etc., are classed as construction timbers. The quantity of construction timbers treated by the plants of the country in 1920 was 139,749,738 board feet, and of this amount 79,513,756 board feet were reported by the plants of the Southern Coast Region. The next largest quantity, or 22,730,703 board feet, was reported from the Atlantic Coast Region, while the Interior Eastern Region ranked third with 22,176,786 board feet.

Practically all of the standard wood-preserving processes were used in the treatment of construction timbers. Where creosote* was the preservative used the average absorption per cubic foot of wood was 10.59 pounds. For zinc chloride it was 0.495 lb., and for the zinc-creosote emulsion it was 0.52 lb. of the former and 4.66 lbs. of the latter.

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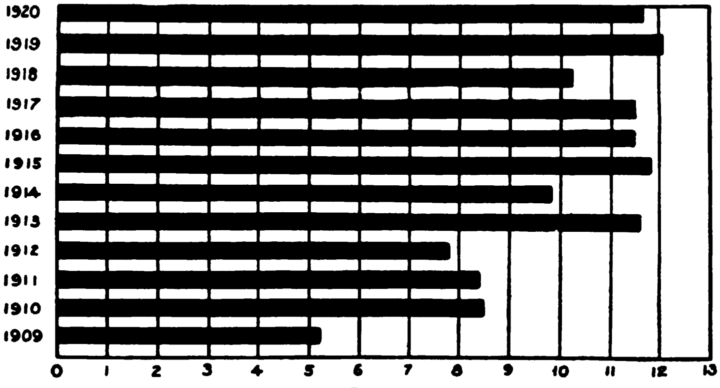
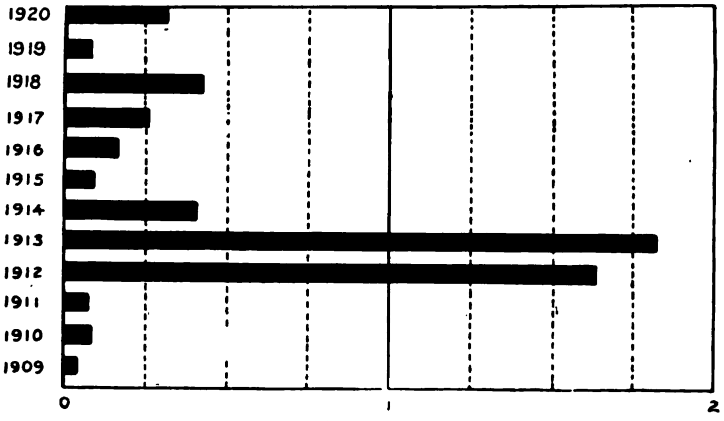
*Includes distillate coal-tar creosote, creosote coal-tar solution, refined water-gas tar and water-gas tar solution.



CONSTRUCTION TIMBER TREATED

Preservation of Cross-Arms.

The number of cross-arms treated in 1920 exceeded the number reported in 1919 by 392,703. The total number treated during the year covered by this report was 514,210, and of this quantity 382,699, or approximately 75%, were reported by the plants of the Southern Coast Region.

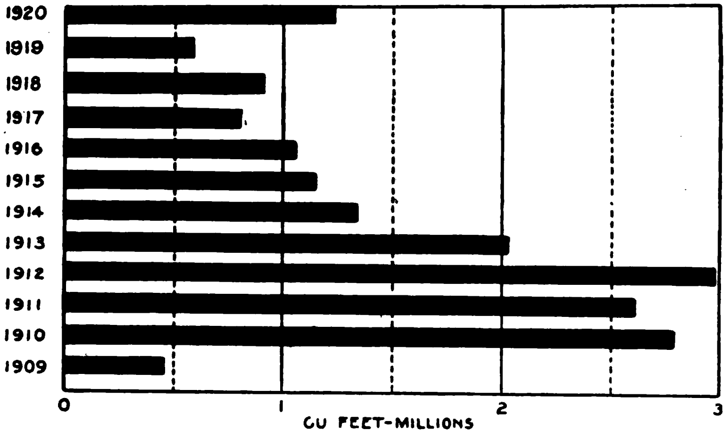


CROSS-ARMS TREATED

Creosote* was the only preservative used in the treatment of cross-arms, the processes employed being the Bethell, Full-Cell and Rueping, and the average absorption was 9.35 lbs. per cubic foot.

Preservation of Miscellaneous Lumber.

The material included under this classification consists of a wide range of wooden commodities. Some of the more important items include crossing-plank, shingles, posts, anchor-slugs, pile-heads, mine-props and lagging, tie-plugs, pole-steps, pipe-staves, electric and signal wire conduit and miscellaneous lumber and dimension material. The total quantity of this class of timber products treated in 1920 was 14,864,274 board feet, representing the substantial increase over the quantity reported in 1919 of 6,750,645 board feet.



LUMBER AND MISCELLANEOUS TREATED

Where creosote* was used alone the average injection of the preservative per cubic foot of wood was 9.86 pounds. For zinc chloride by itself it was 0.492 lb., and for the zinc-creosote combination the absorption was 0.50 lb. of the zinc and 3 lbs. of creosote. The processes used in treating this class of material were the Bethell, Boiling, Burnett, Card, Colman, Lowry and Rueping.

Total Material Treated.

Table 9 shows in cubic feet the total quantity of the different classes of material treated with the various preservatives used for the years 1909 to 1920, inclusive.

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*Includes distillate coal-tar creosote, creosote coal-tar solution, refined water-gas tar and water-gas tar solution.

TABLE 9.—COMPARATIVE STATEMENT OF MATERIAL TREATED IN THE UNITED STATES—1909 TO 1920.
(CUBIC FEET.)

Preservative	Year	Cross-ties	Piles	Poles	Wood-Blocks	Cross-Arms	Construction Timbers	Lumber and Miscellaneous	Total Material Treated
Creosote	1909	29,830,080	4,421,726	659,664	2,994,290	41,764	4,902,311	417,787	43,267,622
	1910	44,525,229	5,219,254	255,597	4,692,453	88,069	7,801,272	2,687,713	65,269,587
	1911	49,532,163	4,937,363	106,213	10,145,724	71,961	7,417,105	2,499,995	74,710,524
	1912	57,461,515	7,624,939	1,169,981	7,091,658	1,643,128	6,892,493	2,841,195	84,724,909
	1913	75,998,307	7,630,328	2,367,769	6,810,308	1,818,010	10,303,883	1,853,993	106,782,598
	1914	67,774,329	7,804,657	1,188,511	3,127,506	395,403	8,389,158	1,348,566	90,028,130
	1915	51,231,207	6,288,238	2,336,318	6,064,758	87,373	9,264,164	881,028	76,153,086
	1916	62,576,403	8,524,680	6,303,954	7,205,953	178,210	9,521,609	691,870	95,002,679
	1917	48,635,554	8,493,715	5,930,559	4,610,427	289,764	7,830,673	706,084	76,496,776
	1918	34,638,147	7,620,974	4,540,620	4,825,766	210,903	7,606,153	707,294	60,149,857
	1919	44,938,215	9,151,972	6,649,491	3,372,828	75,310	9,220,880	553,750	73,962,446
	1920	40,114,551	8,013,192	10,309,746	6,741,410	318,707	9,054,413	1,139,307	75,691,326
Zinc chloride	1909	24,153,162	(a)	(a)	(a)	(a)	320,891	3,333	24,476,386
	1910	27,587,583	(a)	(a)	(a)	(a)	541,514	71,060	28,200,157
	1911	28,337,833	(a)	(a)	(a)	(a)	1,043,851	119,981	29,501,665
	1912	28,532,874	(a)	18,246	(a)	(a)	259,972	20,092	28,831,184
	1913	36,051,816	(a)	47,996	(a)	(a)	585,756	7,670	36,693,238
	1914	50,020,755	(a)	(b)	(a)	(a)	1,317,925	4,355	51,343,035
	1915	53,457,852	4,726	(a)	(a)	(a)	2,406,150	275,279	56,144,007
	1916	43,859,028	859	164	(a)	(a)	1,526,881	346,047	45,732,979
	1917	44,529,954	7,093	45,788	10,421	(a)	2,127,872	5,070	46,726,198
	1918	51,166,146	57,845	(a)	13,939	(a)	2,337,169	30,790	53,605,889
	1919	58,912,323	2,919	(a)	(a)	(a)	2,164,007	63,987	61,143,236
	1920	87,398,160	(a)	(a)	(a)	(a)	1,823,437	94,151	89,315,748
Zinc-creosote	1909	8,095,794	(a)	(a)	(a)	(a)	62,918	43,699	8,202,411
	1910	6,354,219	38,392	(a)	(a)	(a)	181,143	30,646	6,604,400
	1911	7,312,874	(b)	(a)	(a)	(a)	(b)	(b)	7,312,874
	1912	8,214,303	97,874	(a)	(a)	(a)	560,613	99,367	8,972,157
	1913	6,938,838	327,594	(a)	(a)	(a)	758,989	53,628	8,079,049
	1914	5,868,834	(a)	(a)	(a)	(a)	140,718	(b)	6,009,552
	1915	6,548,136	2,320	110,220	(a)	(a)	40,396	4,822	6,705,814
	1916	5,935,242	837	53,933	(a)	(a)	859,428	(a)	6,849,440
	1917	6,482,046	(a)	(a)	(a)	(a)	1,102,635	847	7,585,528
	1918	6,023,334	167,438	12,300	76,393	209,927	164,813	125,327	6,779,532
	1919	8,850,222	14,059	(a)	(a)	(a)	562,403	58,399	9,485,083
	1920	7,414,866	79,354	(a)	(a)	(a)	484,123	5,231	7,983,574

TABLE 9.—COMPARATIVE STATEMENT OF MATERIAL TREATED IN THE UNITED STATES—1909 TO 1920. (CUBIC FEET.) (Concluded.)

Preservative	Year	Cross-ties	Piles	Poles	Wood-Blocks	Cross-Arms	Construction Timbers	Lumber and Miscellaneous	Total Material Treated
Miscellaneous	1909	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
	1910	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
	1911	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
	1912	2,974,317	14,222	352	305,437	(a)	80,446	28,082	3,402,806
	1913	1,792,287	(a)	84,655	45,185	11,709	(a)	124,367	2,059,003
	1914	7,877,043	257,245	298,896	3,741,864	22,511	(a)	9,363	12,201,922
	1915	19,560	(a)	66,242	1,643,213	3,254	123,377	330	1,855,976
	1916	37,431	56,458	389,031	2,738,731	2,634	166,183	47,416	3,437,884
	1917	680,856	85,204	749,156	4,464,382	16,274	433,896	100,316	6,530,084
	1918	(a)	463,115	62,850	1,381,196	2,541	107,458	60,452	2,077,612
	1919	3,021	(a)	11,775	1,340,850	(a)	114,583	(a)	1,470,229
	1920	35,019	(a)	(a)	(a)	(a)	283,838	(a)	318,857
All preservatives	1909	62,079,086	4,421,726	659,664	2,994,290	41,764	5,286,120	463,819	75,946,419
	1910	78,467,031	5,257,646	255,597	4,692,453	88,069	8,523,929	2,789,419	100,074,144
	1911	85,182,420	4,987,363	106,213	10,145,724	71,961	8,460,956	2,619,926	111,524,563
	1912	97,183,009	7,787,035	1,188,579	7,397,095	1,643,128	7,793,524	2,988,686	125,931,056
	1913	120,781,248	7,957,922	2,500,420	6,856,293	1,824,719	11,653,628	2,089,658	153,613,888
	1914	131,540,961	8,061,902	1,482,407	6,869,370	417,914	9,847,801	1,362,284	159,582,639
	1915	111,256,755	6,295,284	2,512,780	6,707,971	90,627	11,834,087	1,161,459	140,858,963
	1916	112,408,104	8,582,834	6,747,082	9,944,684	180,844	11,574,101	1,085,333	150,522,982
	1917	100,378,410	8,586,012	6,725,503	9,085,230	256,038	11,495,076	812,317	137,338,586
	1918	91,827,627	8,309,372	4,615,770	6,297,294	423,371	10,215,593	923,363	122,612,890
	1919	112,703,781	9,168,950	6,661,266	4,718,678	75,310	12,061,873	676,136	146,060,994
	1920	134,962,596	8,092,546	10,309,746	6,741,410	318,707	11,645,811	1,238,689	173,309,505

(a) No statistics. (b) Figures if used would reveal identity of reporting firms.

Converting factors

To obtain the number of cross-ties, divide figures shown by 3.
To obtain the number of linear feet of piling, divide the figures shown by .6763.
To obtain the number of poles, divide the figures shown by 17.6.
To obtain the number of square yards of wood blocks, divide the figures shown by 2.625.
To obtain the number of board feet of construction timbers, multiply the figures shown by 12.
To obtain the number of cross-arms, divide the figures shown by .6198.
To obtain the number of board feet of lumber and miscellaneous material, multiply the figures shown by 12.

APPENDIX

WOOD-PRESERVING PLANTS IN UNITED STATES, CANADA AND MEXICO.

UNITED STATES

(PRESSURE PROCESSES)

Managing Company	Headquarters	Location of Plant	Year Built	Cylinders		
				No.	Diameter Inches	Length Feet
American Creosoting Co.	New York, N. Y.	Newark, N. J.	1906	1 1	78 78	105 165
American Creosoting Co.	Louisville, Ky.	Indianapolis, Ind.	1918	2	64	134
American Creosoting Co.	Louisville, Ky.	Marion, Ill.	1907	2	84	134
American Creosoting Co.	Louisville, Ky.	Springfield, Mo.	1917	2	84	134
American Creosoting Co.	Louisville, Ky.	Kansas City, Mo.	1907	2	84	134
American Creosoting Co.	Louisville, Ky.	Russell, Ky.	1915	1	84	134
American Creosoting Co.	Louisville, Ky.	Hugo, Okla.	1907	2	84	134
American Creosote Works	New Orleans, La.	Southport, nr. New Orleans	1901	1 1	84 108	172 172
American Creosote Works	New Orleans, La.	Louisville, Miss.	1912	1	108	172
American Creosote Works	New Orleans, La.	Winnfield, La.	1906	1 1	72 72	126 80
Anaconda Copper Mining Co.	Butte, Mont.	Rocker, Mont.	1910	1	72	43
A. T. & S. F. Rwy. Co.	Topeka, Kan.	Albuquerque, N. M.	1908	2	74	132
Atlantic Coast Line R. R. Co.	Wilmington, N. C.	Gainesville, Fla.	1912	2	74	138
Atlantic Creo. & W. P. Wks.	Norfolk, Va.	Norfolk, Va.	1901	1 1 1	78 78 78	62 82 126
Ayer & Lord Tie Co.	Chicago, Ill.	Grenada, Miss.	1904	4	74	128
Ayer & Lord Tie Co.	Chicago, Ill.	Argenta, Ark.	1907	4	74	132
Ayer & Lord Tie Co.	Chicago, Ill.	Carbondale, Ill.	1902	4 4	72 74	122 132
Baltimore & Ohio R. R. Co.	Baltimore, Md.	Green Spring, W. Va.	1912	2	84	132
Boston Elevated Rwy. Co.	Boston, Mass.	S. Boston, Mass.	1916	1	90	51
Buffalo, Rochester & Pittsburgh R. R.	Rochester, N. Y.	Bradford, Pa.	1910	1	75	95
Bunker Hill & Sullivan Mg. Co.	Kellogg, Idaho	Kellogg, Idaho	1908	1	84	10
Carbolineum Wood Press. Co.	Portland, Ore.	Portland, Ore.	1901	1	....	....
Central Creosoting Co.	Chicago, Ill.	Finney, Ohio	1918	2	72	134
Central of Ga. R. R. Co.	Macon, Ga.	Macon, Ga.	1912	2	84	116
Central R. R. of New Jersey	Port Reading, N. J.	Port Reading, N. J.*	1912	2	88	140
Charlotte Harbor & No. Ry. Co.	Boca Grande, Fla.	Hull, Fla.	1912	1	74	73
C., B. & Q. R. R. Co.	Chicago, Ill.	Galesburg, Ill.	1907	5	74	132
C., B. & Q. R. R. Co.	Chicago, Ill.	Sheridan, Wyo.	1899	2	74	132
Chicago & N. W. Ry. Co.	Chicago, Ill.	Escanaba, Mich.	1903	3	72	112
Chicago & N. W. Ry. Co.	Chicago, Ill.	Riverton, Wyo.	1915	1	72	110
Colman Co., J. M.	Seattle, Wash.	W. Seattle, Wash.	1884	8	75	120
Colonial Creosoting Co.	Louisville, Ky.	Bogalusa, La.	1912	2	72	134
Columbia Creosoting Co.	Portland, Ore.	Linnton, nr. Portland, Ore.	1912	1 1	72 72	132 65
Compressed Wood Pre. Co.	Cincinnati, O.	Cincinnati, O.	1909	2	72	76

*Operated jointly with the Philadelphia & Reading R. R. Co.

UNITED STATES—(PRESSURE PROCESSES—Continued.)

Managing Company	Headquarters	Location of Plant	Year Built	Cylinders		
				No.	Diameter Inches	Length Feet
Continental Tie & Lbr. Co	Denver, Colo	Cimarron, N. M	1913	1	84	87
El Paso & S. W. R. R. Co	El Paso, Texas	Alamogordo, N. M	1902	2	72	106
Eppinger & Russell Co	New York, N. Y	Long Island City, N. Y.	1878	4	72	100
Eppinger & Russell Co	New York, N. Y	Jacksonville, Fla	1909	3	84	130
Federal Creosoting Co	Louisville, Ky	Bound Brook, N. J	1909	1	84	150
Federal Creosoting Co	Louisville, Ky	Toledo, Ohio	1909	3	84	134
Federal Creosoting Co	Louisville, Ky	Rome, N. Y	1910	2	84	150
Federal Creosoting Co	Louisville, Ky	Paterson, N. J	1909	1	84	150
Georgia Creosoting Co	Louisville, Ky	Brunswick, Ga	1915	2	84	121
Great Northern Ry. Co	St. Paul, Minn	Somers, Mont	1901	4	72	110
Gulfport Creosoting Co	Gulfport, Miss	Gulfport, Miss	1906	2	84	120
Hattiesburg Creosoting Co	Hattiesburg, Miss	Hattiesburg, Miss	1920	2	84	150
Indiana Creosoting Co	Louisville, Ky	Bloomington, Ind	1907	1	84	134
Indiana Tie Co	Evansville, Ind	Evansville, Ind	1907	2	72	110
Indiana Tie Co	Evansville, Ind	Joppa, Ill	1909	2	72	110
Indiana Zinc Creosoting Co	Terre Haute, Ind	Terre Haute, Ind	1904 1912	2 2	72 132	120 20
Interstate Public Service Co	Indianapolis, Ind	Columbus, Ind	1909	1	72	45
Int'l. Creo. & Con. Co	Galveston, Tex	Beaumont, Tex	1892 1897	1	108	140
Int'l. Creo. & Con. Co	Galveston, Tex	Galveston, Tex	1905	1	72	100
Int'l. Creo. & Con. Co	Galveston, Tex	Texarkana, Ark	1902	1 1	114 72	165 125
Jennison-Wright Co	Toledo, Ohio	Toledo, Ohio	1910	2	72	130
Kettle River Co	Madison, Ill	Madison, Ill	1909	4	84	135
L. & N. R. R. Co	Louisville, Ky	Guthrie, Ky	1913	2 1	84 72	133 115
L. & N. R. R. Co	Louisville, Ky	Gautier, Miss	1895 1916	1 1	72 84	133 133
Los Angeles & S. L. R. R. Co	Los Angeles, Cal	Zinc, Cal	1908	2	72	117
Michigan Wood Preserving Co	Pittsburgh, Pa	Reed City, Mich	1913	1	90	90
Midland Creosoting Co	Toledo, Ohio	Granite City, Ill	1917	3	74	140
Mo., Kan. & Tex. Ry. Co	St. Louis, Mo	Denison, Tex	1909	4	72	108
Moss Tie Co., T. J	St. Louis, Mo	Mt. Vernon, Ill	1899	1 1	74 72	132 117
Moss Tie Co., T. J	St. Louis, Mo	Granville, Wis	1921	1 1	74 74	118 132
Moss Tie Co., T. J	St. Louis, Mo	E. St. Louis, Mo	1921	2	76	150
Nat'l. Lbr. & Creo. Co	Texarkana, Ark	Texarkana, Tex	1910	2	84	132
Nat'l. Lbr. & Creo. Co	Texarkana, Ark	Houston, Tex	1912	4	72	120
Nat'l. Lbr. & Creo. Co	Texarkana, Ark	Kansas City, Mo	1920	2	80	84
Norfolk & Western Ry. Co	Roanoke, Va	E. Radford, Va	1921	2	84	140

UNITED STATES—(PRESSURE PROCESSES—Continued.)

Managing Company	Headquarters	Location of Plant	Year Built	Cylinders		
				No.	Diameter Inches	Length Feet
Norfolk Creosoting Co.	Norfolk, Va.	Buell, nr. Norfolk, Va.	1896 1905	4 1 1	78 78 84	100 105 125
Northern Pacific Co.	St. Paul, Minn.	Brainerd, Minn.	1907	2	84	134
Northern Pacific Co.	St. Paul, Minn.	Paradise, Mont.	1907	2	84	133
Ohio Wood Preserving Co.	Pittsburgh, Pa.	Orrville, Ohio	1912	1	84	90
Ore. Short Line R. R. Co.	Salt Lake City, Utah	Pocatello, Idaho	1921	1	84	132
Ore.-Wash. R. R. & Nav. Co.	Portland, Ore.	Wyeth, Ore.	1904	4	72	114
Pacific Creosoting Co.	Seattle, Wash.	Eagle Harbor, Wash.	1906	8	73	125
Pennsylvania System	Philadelphia, Pa.	Mt. Union, Pa.	1909	1	72	132
Pennsylvania System	Philadelphia, Pa.	Greenwich, Philadelphia, Pa.	1910	2	72	132
Phila. & Reading Ry.	Port Reading, N. J.	Port Reading, N. J.*	1912	2	88	140
Pioneer Lbr. & Creo. Co.	Ensley, Ala.	Ensley, Ala.	1911	1	74	76
Pittsburgh Wood Preserving Co.	Pittsburgh, Pa.	Connellsville, Pa.	1911	1	84	90
Puget Sound Wd. Pres. Co.	Lowell, Wash.	Lowell, Wash.	1895	1 1 1	84 73 74	117 120 122
Railway Tie Treating Co.	New York, N. Y.	Portable, Pa.	1917	8	48	63
Republic Creosoting Co.	Indianapolis, Ind.	Mobile, Ala.	1906	2	74	130
Republic Creosoting Co.	Indianapolis, Ind.	Indianapolis, Ind.	1908	1	74	130
Republic Creosoting Co.	Indianapolis, Ind.	Seattle, Wash.	1916	1	74	130
Republic Creosoting Co.	Indianapolis, Ind.	Minneapolis, Minn.	1905	2	74	130
Republic Creosoting Co.	Indianapolis, Ind.	Norfolk, Va.	......	......	......	......
St. Helens Creosoting Co.	Portland, Ore.	St. Helens, Ore.	1912	4	84	136
St. Paul & Tacoma Lbr. Co.	Tacoma, Wash.	Tacoma, Wash.	1912	1	84	130
Santa Fe Tie & Lbr. Preserving Co.	Topeka, Kans.	Somerville, Tex.	1906	5	74	132
Savannah Creosoting Co.	New Orleans, La.	Savannah, Ga.	1920	2	96	140
Shreveport Creosoting Co.	Louisville, Ky.	Shreveport, La.	1910	2	84	134
Shreveport Creosoting Co.	Louisville, Ky.	Deridder, La.	......	......	......	......
Southern Creosoting Co.	Slidell, La.	Slidell, La.	1879 1902	1 2	84 72	150 100
Southern Pacific Co.	San Francisco, Cal.	Latham, Ore.	1898	2	72	117
Southern Pacific Co.	San Francisco, Cal.	W. Oakland, Cal.	1887	1 1	72 72	108 138
Southern Pacific Co.	San Francisco, Cal.	Los Angeles, Cal.	1907	2	72	112
Southern Paving & Const. Co.	Chattanooga, Tenn.	Pensacola, Fla.	1912	1	72	90
Southern Wood Pres. Co.	Atlanta, Ga.	Atlanta, Ga.	1908	1	72	100
Tenn. C. I. & R. R. Co.	Birmingham, Ala.	Bessemer, Ala.	1909	1	72	65
Texas & N. O. R. R. Co.	Houston, Texas	Houston, Tex.	1890	5	72	112

*Operated jointly with the Central Railroad of New Jersey.

UNITED STATES—(PRESSURE PROCESSES—Concluded.)

Managing Company	Headquarters	Location of Plant	Year Built	Cylinders		
				No.	Diameter Inches	Length Feet
Union Pacific R. R. Co.	Omaha, Neb.	Laramie, Wyo.	1909 1903	4 2	73 78	117 117
U. S. Gov't Wood Pres. Plant	New Orleans, La.	New Orleans, La.	......	......	......	......
U. S. Wood Preserving Co.	New York, N. Y.	Buell (nr. Norfolk), Va.	1907	2	78	150
Western Wood Pres. Co.	Spokane, Wash.	Yardley, Wash.	1912	1	84	65
Wyckoff Pipe & Creo. Co.	New York, N. Y.	Portsmouth, Va.	1881	4	74	102
Watkins Creosoting Co.	Chicago, Ill.	Metropolis, Ill.	1913	1	74	100
Walsh Tie Co.	Minneapolis, Minn.	Minnesota Transfer, St. Paul, Minn.	1921	2	72	123

CANADA

Managing Company	Headquarters	Location of Plant	Year Built	No.	Diameter Inches	Length Feet
Bruce & Co., Alex.	Glasgow, Scotland	Fort Francis, Ont.	1912	1	84	76
Canada Creosoting Co., Ltd.	Toronto, Can.	Sydney, N. S.	1911	1	78	85
Canada Creosoting Co., Ltd.	Toronto, Can.	Transcona, Man. (nr. Winnipeg)	1912	1 3	78 78	94 135
Canada Creosoting Co., Ltd.	Toronto, Can.	Sudbury, Ont.	1920	2	84	150
Dominion Creo. Co., Ltd.	Vancouver, B. C.	Vancouver, B. C.	1910	2	90	100
Dominion Tar & Chem. Co.	Sydney, N. S.	Sydney, N. S.	1911	1	78	85
Dominion Tar & Chem. Co.	Sydney, N. S.	Transcona (nr. Winnipeg), Manitoba	1912	1 3	78 78	84 135
Vancouver Creosoting Co., Ltd.	Vancouver, B. C.	N. Vancouver, B. C.	1916	2	84	135

UNITED STATES—(NON-PRESSURE PROCESSES)

Managing Company	Headquarters	Location of Plant	Year Built	Cylinders or Tanks	
				No.	Size—Feet
Allen & Son Co., Otis Allen & Son Co., Otis	Lowell, Mass Lowell, Mass	Lowell, Mass Portsmouth, N. H.	1848 1875	2 4	4 x 8 x 50 4 x 8 x 50
Anaconda Copper Mining Co.	Butte, Mont.	Rocker, Mont.	1909	1	10 x 10 x 10
Baxter & Jordan	Los Angeles, Cal.	Wilmington, Cal.	1911	......	....
Brown Company	Portland, Me.	Portland, Me.	1888	2	5 x 11 x 35
Carbolineum Wood Pres. Co.	Portland, Ore.	Durbin, Ore.	1910	4	3 x 4 x 60
Chapin Co., E. T.	Spokane, Wash.	Bovil, Idaho	1915	2	8 x 12 x 11
Del. Lack & West. R. R. Co.	Scranton, Pa.	Paterson, N. J.	1907	1	6 dia. x 32
Homestake Mining Co.	Lead, S. D.	Lead, S. D.	1908	1	4 dia. x 38
Lindsley Bros. Co. Lindsley Bros. Co.	Spokane, Wash. Spokane, Wash.	Minneapolis, Minn. Priest River, Idaho	1916 1910	2 2	14 x 18 x 11 5 dia. x 11
National Pole Co.	Everett, Wash.	Everett, Wash.	1916	4	30 x 7 x 10
Naugle Pole & Tie Co. Naugle Pole & Tie Co.	Chicago, Ill. Chicago, Ill.	Chicago, Ill. Pinconning, Mich.	1912 1920	2	5 x 5 x 10 ....
New Southern California Edison Co.	Los Angeles, Cal.	Los Angeles, Cal.	1912	3	10. 5 x 8.5 x 9
Page and Hill Co.	Minneapolis, Minn.	Minneapolis, Minn.	1911	4	6 dia. x 11
P. & R. Coal & Iron Co.	Pottsville, Pa.	New Philadelphia, Pa.	1908	1	6 dia. x 32
Portland Ry. Light & Power Co.	Portland, Ore.	Portland, Ore.	......	......	....
Public Service Electric Co.	Newark, N. J.	Newark, N. J.	1909	1	10 x 32 x 2
Puget Sound Wd. P. Co.	Lowell, Wash.	Lowell, Wash.	1895	1	3 x 10 x 30
Republic Creosoting Co.	Mobile, Ala.	Mobile, Ala.	1912	1	8 x 19 x 10
San Joaquin L. & P. Co.	Fresno, Cal.	Fresno, Cal.	1910	2	7 x 9 x 9
St. Paul & Tacoma Lbr. Co.	Tacoma, Wash.	Tacoma, Wash.	1915	4	7 x 10 x 30
Southern Pacific Co.	San Francisco, Cal.	West Oakland, Cal.	1911	1	4 x 6 x 8
United Gas Imp. Co.	Philadelphia, Pa.	Philadelphia, Pa.	......	......	....
U. S. Gov't Wood Pres. Plant	Milan, Ill.	Milan, Ill.	1908	1	4 x 3 x 42
Valentine-Clark Co.	Minneapolis, Minn.	Minnesota Transfer, St. Paul, Minn.	1908 1908	1 2	12 x 14 x 12 8 dia. x 12
Walsh Tie Co.	Minneapolis, Minn.	Minneapolis Transfer, St. Paul, Minn.	1921	6	10 x 22 x 11
Western Cedar Pole Preservers	Spokane, Wash.	Sandpoint, Idaho	1916 1916	2 1	8 x 24 x 11 5 dia. x 11

CANADA

Lindsley Bros.	Spokane, Wash.	Naskup, B. C.	1910	1	6 dia. x 12

MEXICO

No data available regarding treating plants in Mexico. The Mexican Central Railroad built a plant at Aguascalientes, Mex., in 1901, to treat railroad ties with zinc chloride. About the year 1907 the Madero Co. built a 2-retort plant at Madera, Chihuahua, Mex., to treat railroad ties with zinc chloride.

MILEAGE OF STEAM, HORSE AND ELECTRIC RAILWAYS IN THE UNITED STATES.

CROSS-TIES TREATED—TREATING PLANTS IN OPERATION.

Year	Steam Railroads		Horse & Elec. Rwys.	Total	Ties used	Ties treated		Treating plants in operation
	First main tracks	Other tracks						
	Miles	Miles	Miles	Miles	Number	Number	Per Cent.	Number
1860	30,626	3,000	200	33,826	10,147,800	From 1860 to		
1870	52,922	9,100	1,200	63,222	18,966,600	1885 inclusive	0.10	3
1880	93,267	21,977	2,000	117,244	35,173,200	Approx. 50,000		
1885	123,320	32,868	2,800	158,988	47,696,400	120,000	0.25	5
1886	125,185	34,441	3,120	162,746	48,823,800	510,000	1,04	5
1887	137,028	37,348	3,680	178,056	53,416,800	594,000	1.11	5
1888	145,387	38,221	4,112	187,720	56,316,000	644,000	1.14	6
1889	153,725	42,242	4,930	200,897	60,269,100	615,000	1.02	7
1890	163,597	42,036	5,241	213,874	64,168,200	650,000	1.01	8
1891	168,403	47,746	6,155	222,304	66,691,200	697,000	1.05	8
1892	171,564	50,787	7,040	229,391	68,817,300	790,000	1.15	9
1893	176,461	53,676	8,870	239,007	71,702,100	812,000	1.13	10
1894	178,709	54,825	8,949	242,483	72,744,900	920,000	1.26	11
1895	180,657	56,237	10,810	247,704	74,311,200	1,289,000	1.73	12
1896	182,777	57,352	12,133	252,262	75,678,600	1,307,000	1.73	13
1897	183,284	58,729	13,756	255,778	76,733,400	1,312,000	1.71	13
1898	184,648	60,686	15,942	261,276	78,382,800	1,826,000	2.33	13
1899	187,535	62,608	17,665	267,808	80,342,400	2,510,000	3.12	15
1900	192,556	66,228	19,314	278,098	83,429,400	2,800,000	3.36	15
1901	195,562	69,790	22,217	287,569	86,270,700	4,101,000	4.75	17
1902	200,155	74,041	25,592	299,788	89,936,400	6,180,000	6.87	22
1903	205,314	78,508	27,754	311,576	93,472,800	9,010,000	9.64	27
1904	212,243	84,830	29,548	326,621	97,986,300	12,800,000	13.06	30
1905	216,974	89,823	32,517	339,314	77,982,000	14,890,000	19.09	34
1906	222,340	94,643	36,212	353,195	102,884,000	16,880,000	16.41	39
1907	227,455	100,520	38,812	366,787	153,700,000	19,856,000	12.92	51
1908	229,203	103,152	40,247	372,602	111,780,600	23,776,000	21.27	57
1909	234,059	106,950	40,490	381,499	114,449,700	22,033,000	19.25	68
1910	239,447	110,936	40,088	390,471	117,141,300	30,544,000	26.08	78
1911	244,476	116,586	41,088	402,150	120,645,000	31,141,000	25.81	81
1912	247,981	121,386	42,110	411,477	123,443,100	32,394,000	26.24	87
1913	250,534	126,033	43,048	419,615	125,884,500	40,260,000	32.00	92
1914	253,997	130,656	43,989	428,642	147,592,600	43,847,000	34.37	95
1915	257,569	133,573	46,613	437,755	131,326,500	37,085,585	28.24	102
1916	260,144	136,700	47,721	444,565	133,369,500	37,469,368	28.10	117
1917	261,123	139,710	49,587	450,420	135,126,000	33,459,470	24.76	115
1918	262,000	142,000	50,000	454,000	136,200,000	30,609,209	22.47	107
1919	262,000	143,000	50,000	455,000	136,500,000	37,567,927	27.52	108
1920	262,000	145,000	50,000	457,000	137,100,000	44,987,532	32.81	112

Mileage of steam railroads from 1890 to 1914 from records of Interstate Commerce Commission.

Cross-ties used and treated from 1906 to 1911 from Census Reports.

Cross-ties used from 1860 to 1905 and from 1912 to 1918 estimated on basis of 300 ties per mile.

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OF THE

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January 24-25, 1922

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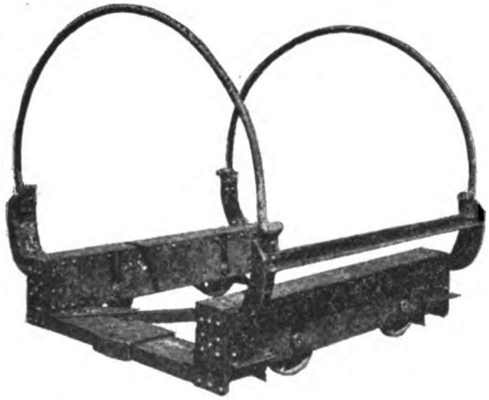

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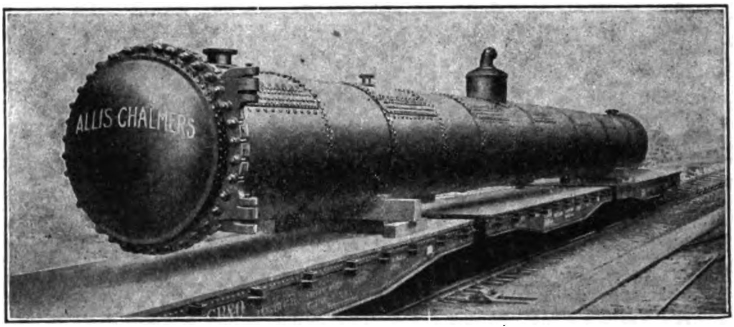

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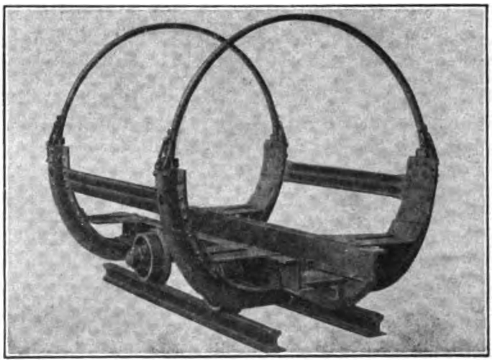

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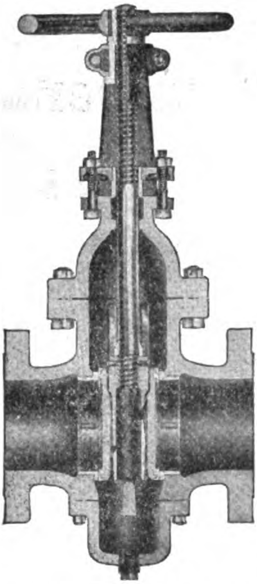

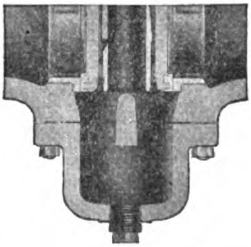

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